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# METALLURGIA

## THE BRITISH JOURNAL OF METALS

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## *The British Journal of Metals*

(INCORPORATING THE METALLURGICAL ENGINEER)

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INCORPORATING "THE METALLURGICAL ENGINEER."

AUGUST 1948 Vol. XXXVIII No. 226

## Quality and Craftsmanship

*If a man write a better book, preach a better sermon or make a better mousetrap than his neighbour, though he build his house in the woods, the world will make a beaten path to his door.*—EMERSON.

THAT quality sells—the fundamental truth behind Emerson's statement—is as true to-day as ever it was. Undoubtedly the practical implications have undergone some modification with time; whilst it might be true that the world would make a beaten path to his door, the time factor would be very large, and an appreciable reduction could be achieved by the judicious use of advertising. So long as the goods advertised are of high quality, advertising can result in continued returns, but if the quality is not there, repeat orders will be non-existent.

The importance of quality, to this country, cannot be too strongly emphasised. Some countries have advantages over us in that their home market is sufficiently large to enable them to take advantage of mass-production methods, others in that their labour costs are appreciably lower. We in Britain have neither of these advantages, and as long as the Lancastrian prefers hot-pot to boiled rice, Lancashire will be unable to compete with some of the Eastern countries in the production of low-quality textile goods and a similar argument could be applied to other industries.

We have led the world in so many developments because of our initiative, ingenuity, industry and craftsmanship. In many cases, other countries have started with the benefit of much of our accumulated experience and, as a consequence, are better equipped from a mechanisation angle and are thereby able to produce more cheaply than we can. Two roads are open to us—either we can re-equip our factories, in many cases from scratch, or we can concentrate on the production of super-quality goods and on new developments. In some directions, the former route holds out some hope of success, but the high standard of living desired, and rightly so, by Britons, means that the labour cost is, of necessity, high. For the second course there is this to be said—a study of a recent review of British exports to the U.S.A., published in an American magazine, leads to the following conclusions—firstly, that many British manufacturers have tried to sell the version of an article that we prefer, rather than study the requirements of the customer, secondly, that the high quality goods find ready markets, and, thirdly, that the finish on some goods left much to be desired.

At one time, British Made was synonymous with quality. We used to pride ourselves that we made nothing shoddy or inferior. Can that be said of us to-day and, if not, why not? One has only to examine the finish of many articles on sale to-day to realise that in appearance, at least, our standards are lower than they were before the war, and although the best is supposed to be reserved for export, it is evident that some of that also lacks quality.

Many reasons may be advanced for this state of affairs, involving discussions of shortages, real and artificial ones created by the dollar saving campaign, attempts to keep down prices, and so on. One aspect—maybe not the major one—which is worthy of consideration is the question of craftsmanship. In the days of the old craft guilds, one of the objects of those honourable institutions was the development and maintenance of high standards of craftsmanship. This should also be one of the objects of their present-day successors, the trade unions, and it would undoubtedly be of great benefit to the community if rather more attention were paid to this aspect of their activities. If we are to maintain our reputation as manufacturers of quality goods, we must increase the numbers of true craftsmen, and by craftsmen is meant not only those who work with hand tools, but also those who can take full advantage of the latest products of the machine tool makers.

It is common knowledge that the foundry trade is suffering from a dearth of apprentices, and whilst engineering possesses its attractions for youth, a considerable number of those entering have no intention of becoming craftsmen—rather do they aspire to a "collar and tie" job at the end of their training. On whose shoulders rests the responsibility for a situation in which few aspire to craftsmanship? Is it the employer, by reason of inadequate financial attraction, or the community, by making it insufficiently attractive socially, or the education system by too great an emphasis on book-work, or the present-day craftsman by being unable to get any satisfaction from a piece of work well done? The late Harry Brearley, than whom the skilled man had no greater advocate, in his book, "Talks on Steel-making," says: "This glow of satisfaction is what makes the workman's self respect, and the need for it is as true of the street sweeper as of the surgeon. It is ordained that if a man shall look on the work of his hands and find it good, his soul shall be satisfied. If he shall find it not good, or if there is nothing to look at, no amount of remuneration and flattery can keep him a sane and happy man."

The wealth of a country lies in its natural resources, and the work which its people can put into them to enhance their market value. One of the disturbing features of present Government policies is the increase in non-productive labour involved. Some of it may be justifiable, but if Britain is to prosper we must ensure that we do not create a bureaucratic machine which denudes production of its labour force.

# Oxygen in Iron and Steel Making

THE idea of using oxygen enrichment can be traced to the earliest days of steelmaking involving the use of air; Henry Bessemer having been aware of its potentialities when developing his converter process. In blast furnace practice, too, it was early appreciated that by raising the oxygen content of the blast the opportunity for direct collision of oxygen and carbon molecules is increased, since the proportion of diluent nitrogen is reduced. Reaction is therefore accelerated and the temperature in the combustion zone is increased. Recent economic changes in the supply of raw materials, especially the potential cheapening of tonnage oxygen, has led to an awakening of interest in the application of oxygen-enrichment to steelmaking processes, not only to the blast furnace, cupola, and converter processes, in which the main application would appear to lie, but also to open-hearth and electric furnaces either for the improvement of thermal efficiency or for the selective oxidation of particular elements such as carbon.

A committee, formed under the auspices of the United States Bureau of Mines, published a report in 1925 of an extensive investigation on oxygen-enrichment in blast furnaces. It recommended that the blast should be enriched so as to contain 31% of oxygen. Under the conditions recommended an increase in production of 18% was estimated. It was claimed that the capital cost and running maintenance charges of the stoves would be saved. At least one application to actual practice was made on a blast furnace at Liége in Belgium about 20 years ago, in which it was claimed that enrichment up to 25% of oxygen enabled the stoves to be dispensed with and a higher grade of pig-iron to be produced. While technical results of the trials apparently confirmed theoretical considerations, no information seems to have been made available regarding the commercial success, or otherwise of the venture. In Germany, also, in 1925, it was shown that oxygen-enrichment applied to the basic Bessemer converter completely altered furnace conditions and that it was possible to make comparatively large steel scrap additions to the superheated-blown metal. Trials showed that with 35% of total oxygen in the blast the blowing time was halved without any increase in loss, and the properties of the finished steel were normal.

In Russia, too, much work has been done on the subject. Trials were made in 1934 when oxygen was introduced into a ladle; subsequently it was stated that the blowing time of a bottom-blown Bessemer converter had been reduced to one minute by the use of oxygen and that the finished steel had excellent properties. It is claimed that the large scale use of oxygen in the Dnepropetrovsk blast furnace plant has been proceeding since 1940–41, and more recently extended to converters, open-hearth furnaces, and other metallurgical operations.

More rapid melting of steel in the open-hearth furnace by the use of oxygen has been demonstrated by recent trials both in Canada and the United States, while at the recent Swiss meeting of the Iron and Steel Institute the potential application of oxygen to various metallurgical processes was discussed. During this discussion reference was made to some trials in a two-ton side-blown converter with 90% oxygen and whilst no further details were given it was also reported that a pig-iron containing only carbon had been satisfactorily converted.

In view of the paucity of reliable information available on the effect of the use of oxygen-enriched air in the side-blown converter the report by Mr. J. L. Harrison, Dr. W. C. Newell and Mr. A. Hartley, given elsewhere in this issue is of outstanding importance. In this work the broad objective before the authors was the desire to attain more easily by combustion the high temperatures necessary for steelmaking.

The fact that air consists of four-fifths of inert nitrogen by volume considerably lowers the maximum limit of temperature attainable by any atmospheric oxidation or combustion process, and that whilst thermal recuperation or regeneration can be applied to certain large-scale processes to regain the sensible heat otherwise carried away with the nitrogen, this is not always possible and is an added plant complication, except in the blast furnace where the ingoing burden itself acts as a thermal recuperative medium. This broad objective can be evaluated as an enhanced degree of freedom in the steel-making process, and it can be expressed in terms of the merits of higher liquid steel temperatures (with all its concomitant merits, such as higher fluidity and increased length of fluid life for handling and refining), or in terms of the fuel economy for both carbon and silicon, not only in the converter itself, but also in the preliminary iron-melting cupola, on account of the lower acceptable liquid iron temperature. The objective can also be evaluated in terms of economy in pig-iron and its increased replacement by steel scrap, and not least by the saving of melting time and the potential increased furnace output and range of application of the converter process.

This investigation has verified and measured in a commercial steel foundry the practicalness of these objectives, and, in addition, it has shown that a closer control of composition is possible. This last point is of particular importance as it was anticipated that the shortening of blowing operation might increase the problem of controlling the composition.

The experimental trials which are described were carried out at the works of Messrs. Catton & Co., Ltd., and as far as possible they were conducted on a production basis. There were several series of trials involving over 200 oxygen-enriched heats and the results clearly indicate that even a moderate degree of oxygen enrichment, applied with little or no modification to existing converter units, can lead to improvement in steel-making practice. There seems no doubt that a closer degree of control can be gained in this steel-making operation, which is a feature of great value, that should favourably influence the future application of the side-blown converter. Apart from effecting closer control the importance of higher steel temperatures that are made possible is an attractive feature to foundries requiring small quantities of steel intermittently, especially where thin-section castings are being made and high fluidity is desired.

From an economic point of view it would seem that economies effected by the use of oxygen-enrichment more than compensate for the cost of adding 1,000–2,000 cu. ft. of oxygen per ton of steel, especially if this cost can be reduced by its more general use. The success of these trials is of such a high order that the use of oxygen enrichment in the operation of side-blown converters may become normal practice in a relatively short time.

# High Creep Strength Austenitic Steel Tubes

By G. T. Harris, M.A., F.Inst.P.; and W. H. Bailey, A.Met.L.I.M.

*Research Department, William Jessop & Sons, Ltd.*

***Although the gas turbine is still popularly associated with the jet propulsion of aircraft, increasing attention is being paid to the development of large installations for land and marine use. In this article, the authors deal with the development of heat resisting steel tubes for use in heat exchangers which form an essential part of such turbines.***

## Introduction.

THE rapid strides that have been made in recent years towards the development of jet propulsion and gas turbine engines both for war and peacetime applications could not have been achieved without the aid of new heat-resisting alloys. The working conditions necessary for turbine rotors and blades were so severe that new alloys having a high creep resistance at the proposed operating temperatures had to be developed and for the most part these temperatures were so high that the use of austenitic alloys was essential.

It is almost inevitable that alloys designed to have a high creep strength at elevated temperatures should be difficult to manipulate by the normal forging and rolling techniques and it was not without intensive research and patience that the large scale production of turbine blades, discs and rotors from such alloys was made possible.

In this country, from the period just before the war, the greatest emphasis was primarily on the use of gas turbines as applied first to the jet propulsion of aircraft and later to include the provision of shaft horsepower for driving a propeller. In Switzerland, however, work was early directed to the development of large power plants for land or marine use, and this was followed by a growing interest in this field by Great Britain and the United States. Of these types of turbine the closed-cycle plant in particular has as an essential part air-heaters and heat-exchangers which presented new problems in the provision of heat-resisting steel tubing. The tubes for such units may range from ½ in. to 2 in. diameter (12 to 50 mm.) with wall thicknesses of about 14 S.W.G. (2 mm.)

In service these tubes may attain an operating temperature of 700° C. to 750° C. and must resist both creep and corrosion by the combustion gases. The stresses involved are of the order of 1 to 3 tons/sq. in. and at the operating temperatures indicated only the highest grades of heat-resisting steel tubing will be capable of extended life. For example, the 18/8 type of austenitic steel stabilised with titanium or niobium would under these conditions stretch within a few thousand hours far more than could be tolerated. It was therefore evident that steels previously developed and extensively used for the high temperature parts of jet and gas turbine engines would be needed to meet the requirements and therefore investigations were carried out to ensure that they could be successfully fabricated into tubes and that the welding properties were adequate to enable complex banks of tubing to be assembled.

Considerable experience had already been gained in forging and rolling Jessop G.18B steel,[1, 2] an alloy which has now been used extensively in gas turbines for about five years for highly stressed, high-temperature components. This alloy was a natural choice for preliminary experiments in the manufacture of tubes from high-temperature materials and an added reason for this selection was the extensive long-time creep data available. The chemical composition of Jessop G.18B is given in Table I, and the creep resistance in Table II for periods up to 30,000 hours, corresponding to over three years.

TABLE I.

CHEMICAL COMPOSITION OF JESSOP G.18B.
(weight: per cent)

| | |
|---|---|
| Carbon .. .. .. .. | 0·4 |
| Manganese .. .. .. | 0·8 |
| Silicon .. .. .. .. | 1·0 |
| Nickel .. .. .. .. | 13·0 |
| Chromium .. .. .. | 13·0 |
| Tungsten.. .. .. .. | 2·5 |
| Molybdenum .. .. .. | 2·0 |
| Niobium .. .. .. .. | 3·0 |
| Cobalt .. .. .. .. | 10·0 |

## Manufacture of Tubes in Jessop G.18B.

Billets of 5·55 in. (141 mm.) dia. and 3·80 in. (96½ mm.) dia. were successfully extruded by the Chesterfield Tube Company on a horizontal type

1 *Journal, West of Scotland Iron and Steel Institute*, 1946–7, Vol. 54, D. A. Oliver and G. T. Harris.

2 *Trans. Institute of Marine Engrs.*, Vol. LIX, No. 5, 1947, D. A. Oliver and G. T. Harris.

TABLE II.—CREEP STRENGTH OF JESSOP G.18B STEEL FOR SPECIFIED STRAINS, TIMES AND TEMPERATURES. STRESSES IN TONS/SQ. IN.

| Temperature | | 650° C. | | | | 700° C. | | | | 750° C. | | | | 800° C. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time hours | Strain % | 0·1 | 0·5 | 1·0 | Rupt. | 0·1 | 0·5 | 1·0 | Rupt. | 0·1 | 0·5 | 1·0 | Rupt. | 0·1 | 0·5 | 1·0 | Rupt. |
| 300 | 0·1<br>0·5<br>1·0<br>Rupt. | 8·0 | 13·0 | 15·0 | 18·6 | 4·9 | 9·3 | 11·2 | 13·8 | 3·6 | 6·4 | 7·9 | 8·2 | 4·0 | 5·3 | 5·7 | 6·4 |
| 1,000 | 0·1<br>0·5<br>1·0<br>Rupt. | 6·6 | 11·4 | 13·6 | 16·0 | 3·6 | 7·7 | 9·4 | 11·4 | 3·3 | 5·9 | 6·6 | 7·3 | 3·9 | 4·8 | 5·0 | 5·6 |
| 3,000 | 0·1<br>0·5<br>1·0<br>Rupt. | 5·8 | 7·8 | 11·4 | 13·8 | 2·7 | 6·8 | 8·2 | 9·9 | 3·0 | 5·4 | 5·6 | (6½) | (3·7) | (4½) | 4·7 | 5·0 |
| 10,000 | 0·1<br>0·5<br>1·0<br>Rupt. | (5) | 6·4 | (9) | 11·8 | — | 6·0 | 7·0 | 8·4 | 2½ | 4½ | (5½) | — | — | (4·2) | (4·4) | (4½) |
| 30,000 | 0·1<br>0·5<br>1·0<br>Rupt. | — | (5·8) | (7) | (10) | — | 5·4 | (6·0) | 7·2 | — | — | — | — | — | — | — | — |

**Fig. 1.—Sample of cold drawn G.18B tube.**

Schœller-Bleckmann machine to hollows of $2\frac{1}{4}$ in. (57 mm.) outside dia. and $1\frac{5}{8}$ in. (41 mm.) outside dia. respectively, provided the preheating and soaking of the billets before extrusion were carefully controlled. After thoroughly soaking at 1,100° C. the temperature was steadily increased to 1,260° C. and five minutes after attaining this temperature the billets were withdrawn and transferred to the extrusion press. The estimated temperature at the commencement of extrusion was 1,240° C.

A careful examination of the extruded hollows revealed no cracks or flaws and after softening by air cooling from a temperature of 1,120° C., the respective hollows were cold drawn in three or four passes to tubing of $1\frac{3}{4}$ in. (44 mm.) outside dia. × 12 S.W.G. (2·64 mm.) and to 1 in. (25 mm.) outside dia. × 10 S.W.G. (3·25 mm.). In addition to the softening treatment prior to cold work, the same treatment was given after the first two passes.

## General Examination of Tubes

An important factor in the selection of a material for air-heater tubes is that the tubes must be clean and free from scale. The general appearance of the cold-drawn tube is excellent in this respect (Fig. 1), but the low creep strength, as described below, makes impracticable the use of material in this state. Since, as for most heat-resisting alloys, the heat-treatment of G.18B involves soaking at a sufficiently high temperature to take various phases into solution, a number of careful tests were carried out to ensure that this high heat-treatment temperature would not cause excessive scaling.

The samples shown in Fig. 2 were heat-treated in an atmosphere-controlled furnace at temperatures of 1,280° C. and 1,300° C. Specimen C, oil quenched from the lower temperature was clean and free from loose scale. Air cooling from 1,280° C. (Specimen B) and from 1,300° C. (Specimen A) produced a certain amount of loose surface scale which was found to be readily removable by pickling.

The photomicrographs shown in Fig. 3 illustrate the effect of heat-treatment on the cold-drawn tube. The grain size in the cold-drawn state was small, with heavily segregated carbides, air cooling from 950° C. had little effect on the microstructure but after air cooling from 1,280° C., a more normal structure, consisting of large well defined recrystallised grains and a uniform carbide distribution was produced.

## Mechanical Properties of Tubes

Strip tensile test-pieces were taken from the tube in the longitudinal direction. These were not of standard dimensions and thus the values obtained for the percentage elongations are only comparative. Tests were taken from the tube in the cold-drawn state, after air cooling from 950° C. and from 1,280° C., and the results obtained are given in Table III.

TABLE III.
LONGITUDINAL TENSILE STRENGTH OF G.18B TUBE.

Gauge Length .. .. 1·00 in.
Width .. .. .. .. 0·301 in.
Thickness .. .. .. 0·081 in.

| Condition | Maximum Stress (tons/sq. in.) | Elongation per cent. |
|---|---|---|
| Cold Drawn .. .. | 75 | 8 |
| Air Cooled, 950° C. .. | 50 | 33 |
| Air Cooled, 1,280° C. .. | 47 | 30* |

* Fractured outside middle half.

It will be seen that, in the cold-drawn state the material had, as expected, a high tensile strength together with a low ductility due to the cold work introduced in the final drawing operation. After air cooling from 950° C. and 1,280° C. complete stress relief had taken place giving the more normal maximum stress values together with a greatly increased ductility.

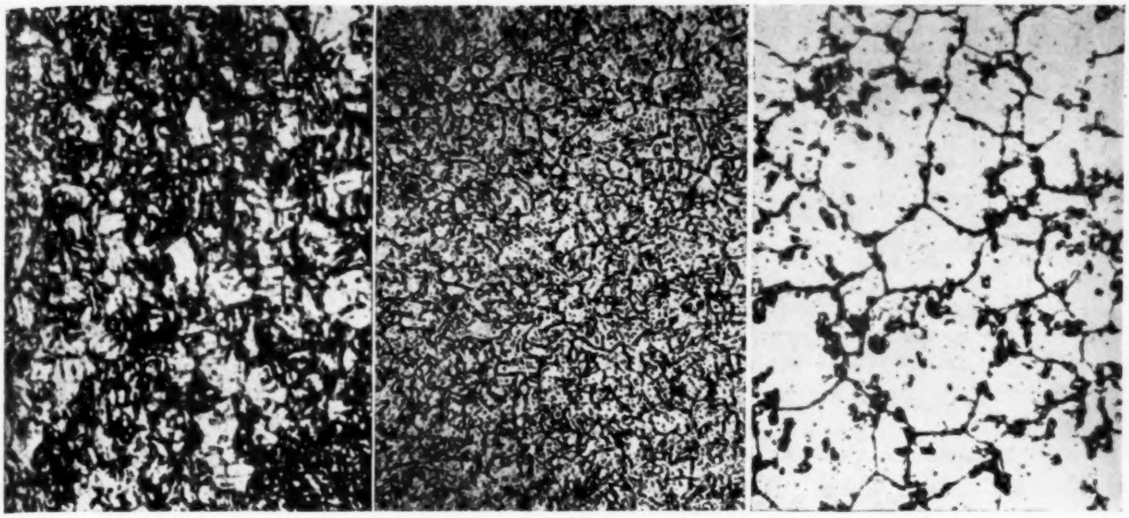
As seen in Table III, a temperature of 950° C. is sufficiently high to stress relieve the cold worked material, and so restore the room temperature tensile properties, but it is not sufficiently high to allow the carbides and other phases to be taken into solution, which is essential for developing maximum creep strength. This was confirmed by the results of creep tests carried out on specimens prepared from the tubes. Special adaptors enabled creep tests to be carried out in a standard 5-ton creep testing machine. Fig. 4 illustrates an unbroken and a broken tube test-piece of the type finally adopted.

For these preliminary tests the strain measurements were made by the use of a dial gauge on the lever arm. This enables creep rates as low as $10^{-6}$ per hour to be measured but includes such errors as bedding down of knife edges and screw threads, so giving slightly erroneous values of the initial creep. A special extensometer attached directly to the tube specimen was not available for these preliminary tests.

At a temperature of 700° C. the creep strength of cold-drawn tube was

A Air cooled from 1,300° C. and pickled. B Air cooled from 1,280° C. C Oil quenched from 1,280° C.

**Fig. 2.—Heat-treated samples of G.18B tube.**



As drawn. × 500. Air cooled from 950° C. × 500. Air cooled from 1,280° C. × 500.

**Fig. 3.—Effect of heat-treatment on micro-structure of G.18B tube.**

found to be approximately 40% lower than that of standard bar material (see Fig. 5), and after air cooling from a temperature of 950° C. no improvement in creep strength was produced. After solution treatment at a temperature of 1,280° C., however, the full creep strength was recovered, and results 30% better than those of standard forged or rolled bar were obtained. The strain/time curves are given in Fig. 6 for cold-drawn tube, heat-treated tube and standard G.18B bar material.

## Welding Characteristics of Jessop G.18B.

In addition to the high standard of scaling resistance, creep strength and corrosion resistance demanded of an alloy for use as air-heater tubes, the material must also be readily weldable as the complicated internal construction of such a unit involves many welded joints. The physical characteristics of each welded joint should approximate closely to those of the parent metal.

An earlier investigation on the welding of G.18B and allied materials had shown that satisfactory welded joints could be made by electric flash-butt, electric arc and solid phase or pressure welding. The quality was judged by room temperature mechanical tests and creep tests at elevated temperatures.

In the construction of an air-heater unit, the welded joints should be internally smooth in order to minimise the resistance offered to the gas flow. This almost eliminates the use of welding processes such as flash-butt welding and solid phase welding, where the production of a good welded joint depends in part on a certain amount of upsetting taking place, which produces an internal flash which would be difficult to remove. The natural choice of method for multiple tube construction is electric arc welding.

TABLE V.—Creep Tests on Solution Treated G.18B Welded with G.18B Electrodes.
Stress: 12 tons/sq. in. Temperature of Test: 700° C.

| Condition | Minimum Creep Rate per hour. | Duration hours. | Elongation % | Creep Strength relative to G.18B % |
|---|---|---|---|---|
| As Welded.. .. .. .. | $1 \cdot 0 \times 10^{-5}$ | 1031 Fractured | 2·9 | 118 |
| Stress-Relieved .. .. .. | $0 \cdot 5 \times 10^{-5}$ | 384 Discontinued | 0·46 | 133 |

## Electric Arc Welding of Jessop Austenitic Steels.

Earlier experiments on the arc welding of heat resisting materials showed that the best welds of G.18B were obtained by using G.18B electrodes. Tensile test results obtained on solution treated G.18B welded in this way with no subsequent heat-treatment are shown in Table IV.

TABLE IV.
Tensile Tests on G.18B—G.18B Welds—G.18B Electrodes.

| | |
|---|---|
| 0·1% Proof Stress, Tons/sq. in... | 21·7 |
| 0·2% Proof Stress, Tons/sq. in... | 23·3 |
| 0·5% Proof Stress, Tons/sq. in... | 25·7 |
| Maximum Stress, Tons/sq. in. .. | 44·3 |
| Elongation (L= 4 √A), % .. | 44 |
| Reduction of Area, % .. .. .. | 50 |

**Fig. 4—G.18B tube creep test pieces.**

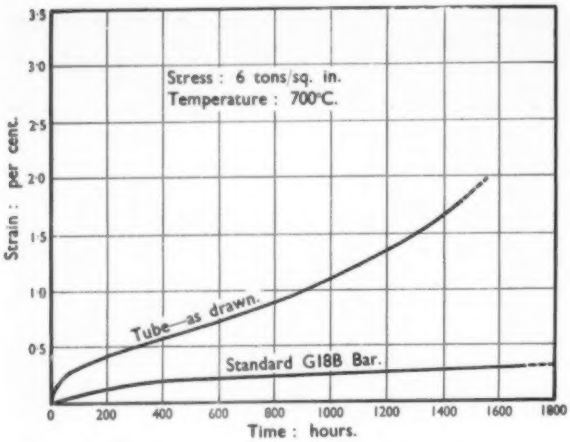



**Fig. 5.—Creep Tests on G.18B tube.**

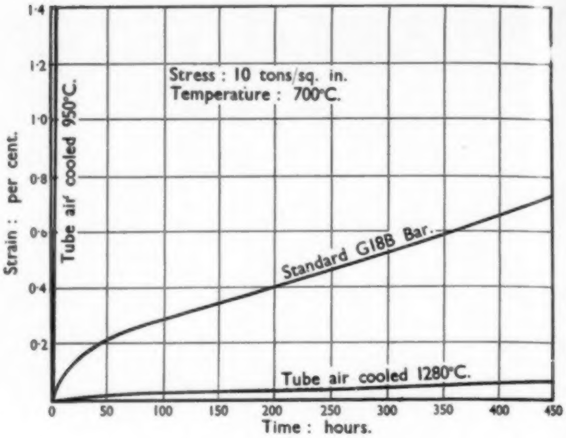



**Fig. 6.—Creep tests on G.18B tube.**

The welded material was extremely ductile, fracture taking place outside the welded region.

Creep tests carried out at 700° C. on welded samples showed that in the "as welded" condition the creep strength was slightly superior to that of standard bar material but that an improvement in creep strength over that of "as welded" material was achieved by a low temperature stress relieving treatment after welding. The results of these creep tests are given in Table V.

Further welding experiments have shown that satisfactory tensile, fatigue and creep strengths can be obtained from both electric flash-butt and pressure welds in G.18B steel and also in Jessop R.20[2,3] which is a simpler austenitic steel having adequate creep strength for many purposes.

For elaborate tubular constructions, therefore, where heat - resisting materials are required it has been shown that the use of G.18B or R.20 would present no practical difficulties. Following extrusion, cold drawing and solution treatment, the tube assemblies can be fabricated by electric arc welding preferably followed by a low temperature stress-relieving treatment.

3 *Iron and Steel*, 1946, Vol. 19, p. 379, D. A. Oliver and G. T. Harris.

Acknowledgement is made to Mr. Naden of the Chesterfield Tube Co., Ltd., for his co-operation in tube production and to Mr. D. A. Oliver, Director of Research, The B.S.A. Group of Companies for continual encouragement.

## Lesser Uses of Copper

Several thousands of tons of copper are now used for small additions to iron, steel, aluminium and other alloys every year, according to the current Bulletin of the Copper Development Association. Prior to the war a considerable quantity of copper-bearing irons and steels were produced annually, the copper content of which normally varied from about 0·5 to 1 per cent., though in some cases it was higher. The consumption of copper for this purpose reached several hundred tons per annum and although, compared with many other uses, the quantity was small, unlike most of them, it represented true consumption. The quantity of copper-bearing irons and steels produced today is less than pre-war, possibly because of a curtailment in the production of special materials in order to facilitate the maximum output of ordinary types. Nevertheless, the iron and steel industry is still a potentially important outlet for copper when the need arises.

In light alloys, also, the consumption of copper is now probably well below the peak figures of a few years ago, partly because of a tendency towards a decreased use of some of the alloys which contain copper. Nevertheless, the majority of cast aluminium alloys still contain up to about 3% of copper, while numerous wrought alloys of the heat-treatable type contain on an average 4% of copper. From the statistics available, it is probable that rather more than 3,000 tons of copper were consumed in light alloys in 1947.

Reference has several times been made to the use of copper for the plumbing in prefabricated aluminium houses and it is interesting to realise that for each of the 69,500 houses so far ordered, nearly 2·25 tons of aluminium alloys containing about 4% of copper are required. Thus the aggregate copper content of the light alloys used for the houses is of the order of 6,000 tons, which is additional to the copper otherwise used in them.

Apart from iron, steel and aluminium alloys, there are many others for which copper is required. Some zinc-base diecasting alloys contain up to 4·5% of copper; while tin-base diecasting alloys, type metals, and bearing alloys may contain from 2–8%. In other alloys, although copper is an essential ingredient, the percentages used are much smaller; for example, lead alloys may contain from 0·07% to as little as 0·005% of copper. On the other hand the high copper content even of some well-known materials is not always appreciated, "9-carat gold", for example, is nearly two-thirds copper.

## Guest, Keen and Nettlefolds (South Wales) Ltd.

It is announced that as from 1st August, 1948, the Works of Guest, Keen & Nettlefolds, Limited, at Castle Works, Cardiff; Cwmbran, near Newport, Mon.; Refractories Works at Henllys, near Newport, Mon., and Viaduct Fireclay Level at Pontnewynydd near Pontypool, Mon., were transferred entirely to a new Company, known as Guest, Keen & Nettlefolds (South Wales), Limited, which is a subsidiary company of Guest, Keen & Nettlefolds, Limited.

# The Application of Oxygen-Enrichment to Side-Blown Converter Practice

By J. L. Harrison*, Dr. W. C. Newell†, and A. Hartley†.

*The practical utility of the use of oxygen-enriched air for side-blown converter practice has been demonstrated in a series of works-scale experiments, the steel produced having been of normal high quality and having been used for commercial castings. The higher thermal efficiency arising from the use of oxygen-enrichment has been evaluated in terms of the various alternative factors, such as shorter blowing time, higher steel temperature and the reduction in silicon and other fuel consumption. It has been shown how the increased flexibility of control of the side-blown converter process has led to a more consistent composition of the steel produced, that a greater productive output from existing plant is now possible, that a higher proportion of scrap can be used in the charge and it is suggested that these factors may lead to an increased use of the side-blown converter process not only in the foundry but also in larger basic furnaces for ingot steel production. Detailed observations made on these trials compare the temperature increments and changes in chemical composition during the blow with normal practice, and it is shown that oxygen-enrichment increases the efficiency of the total oxygen blown into the furnace and that the life of the refractory converter lining is not appreciably diminished.*

### Description of Plant and Apparatus

THE side-blown converters were originally operated as Stock converters, they are now operated as normal converters, but the original oval shape and dimensions remain unchanged, as shown in Fig. 1. The siliceous monolithic lining is uniformly about 13 inches thick, and it is found that owing to the shortness of the body and nose of the converter the blowing loss is rather higher than for the more modern type of converter, the blowing loss averaging 10%. There are six silica-brick two-inch diameter tuyeres spaced ten inches from the bottom of the vessel, which is thus found to have a capacity of 40 to 50 cwts. during the life of the lining, which, during normal operation and without general patching, is about 60 heats. Very little wear occurs below the tuyere level, and the vessel bottoms, which are made of silica brick, remain in position for at least six lining lives. Refractory wear tends to make the interior of the vessel spherical in form, but particular local wear occurs at the tuyeres, above the tuyeres and at the body-nose junction.

Air is supplied to the converters at 3 to 3½ lb. pressure by a positive-displacement Rootes blower, the volume blown being strictly proportional to the speed of rotation, and in fact was calibrated from the tachometer reading attached to the shaft of the motor. The blast rate was normally 2,700 to 3,000 cubic feet per minute, though by control of the speed of the blower between 1,6C0 and 4,C00 cubic feet per minute could be delivered. This lower limit of blowing rate of the air was a limitation upon the oxygen-enrichment trials as will be seen later.

Normally, i.e., before these trials, the cupolas were charged with 20% hæmatite iron, 80% steel scrap and sufficient ferro-silicon was added to give a total silicon content in the molten iron of 1%. The temperature of this metal was 1,320°–1,340° C. and after blowing in the converter this was raised up to 1,660°–1,680° C., or even up to 1,740°–1,750° C. if an addition of about 0·4% of silicon as ferro-silicon was added to the converter during the blowing operation. Owing to the large temperature increment with the oxygen-enrichment trials it was found unnecessary to add silicon with the pig-iron, and the silicon content for those trials was only about 0·5–0·7%. Desulphurising of the molten iron was carried out by means of 30-lb. of soda-ash per ton in a basic-lined ladle. Owing to the poor-quality coke and steel scrap perforce in use the sulphur content of the iron before treatment was between 0·12 and 0·15%, though occasionally values as high as 0·20% were obtained.

After the completion of the blowing operation the slag was removed, except for multiple heats, and for the preliminary trials de-oxidation was carried out by the addition of aluminium rabbled into the bath as a primary de-oxidiser, followed by the addition of ferro-manganese and ferro-silicon. Later this practice was superseded by the use of ferro-manganese and ferro-silicon added to the bath together as primary de-oxidisers and followed by a ladle addition of 21-lb. of calcium-silicon-manganese alloy per ton of steel. The steel was stopper-poured from fire-brick-lined ladles patched with siliceous "compo."

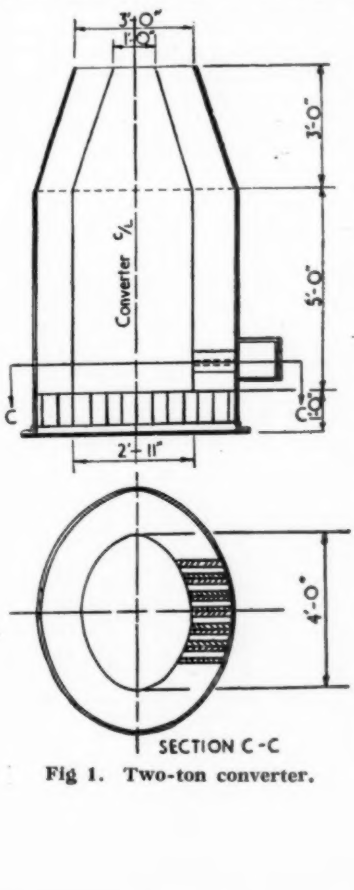



Fig 1. Two-ton converter.

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TABLE I.—PRELIMINARY HEATS

| Cast No. | Total % oxygen | Rate of air blast (cu.ft./min.) | Rate of oxygen addition (from manometer) (cu.ft./min.) | Duration of blow (mins. secs.) | Volume of oxygen addition (from gauge) (cu. ft.) | Volume of oxygen from the air used (cu. ft.) | Total volume of oxygen used (cu. ft.) | % of total oxygen derived from oxygen addition | Weight of cupola metal charged (cwts.) | Blowing loss (%) | Temperature °C. Cupola iron | Temperature °C. Final bath |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 475 | 30 | 2,700 | 400 | 11·0 | 4,400 | 6,000 | 10,400 | 42 | 42 | 4·60 | 1,375 | In excess of 1,750 |
| 476 | | | | 9·0 | 4,000 | 5,000 | 9,000 | 44 | 37 | 11·90 | 1,355 | ,, |
| 477 | | | | 8·0 | 3,500 | 4,500 | 8,000 | 44 | 39 | 11·40 | 1,385 | ,, |
| 480 | | | | 9·0 | 3,500 | 5,000 | 8,500 | 41 | 41½ | 5·70 | 1,345 | ,, |
| 481 | | | | 9·30 | 3,800 | 5,200 | 9,000 | 42 | 43 | 6·50 | 1,345 | ,, |
| 482 | | | | 9·30 | 4,000 | 5,200 | 9,200 | 43 | 42¼ | 6·50 | 1,345 | ,, |
| 487 | 40 | 2,700 | 900 | 5·45 | 5,000 | 3,200 | 8,200 | 61 | 38½ | 16·30 | 1,400 | ,, |
| 492 | | | | 4·30 | 4,000 | 2,500 | 6,500 | 61 | 38½ | 16·30 | 1,360 | ,, |

The oxygen was obtained from an evaporator, already installed in the works for other purposes, of 14,000 cu. ft. capacity and 1,500-lb./sq. in. working pressure. The authors are grateful to the British Oxygen Company for supervising the installation of the oxygen equipment, which included a series of large low-pressure tanks of 14,000 cu. ft. capacity at a pressure of 300-lb. /sq. in. These tanks were filled from the evaporator through a non-return valve, and a pressure-reduction valve from these tanks produced a constant oxygen pressure of 20-lb. /sq. in. It was then fed through a throttling valve into the 2·5 in. diameter pipe from, and close to, the blower. The rate of flow was measured from a simple manometer connected across a calibrated standard orifice plate, which was inserted in a section of the pipe which had been enlarged to a diameter of 4 in. over a straight length of 13 ft. especially for the purpose. The quantity of oxygen flowing was then calculated after making due allowance for the temperature and pressure correction factors. A check of the quantity of oxygen consumed was also obtained from the pressure gauge attached to the low-pressure tanks, and there was always good agreement between the consumption indicated by the two methods. It will be noted in the tables of results that the percentage of the total oxygen which was added as pure oxygen is calculated, as this is higher than the difference between the total percentage of oxygen and the 20·5% present in the air.

## Results

The authors' initial experimental scheme was to keep the Works on a normal production basis as far as possible, and to inject additions of pure oxygen into the air-blast stream so as to increase the total oxygen content of the blast in 10% steps, i.e., 30%, 40%, etc. Table I shows the results obtained from the first few trials with 30% and 40% of total oxygen in the blast. These trials showed that the temperature was easily taken beyond the range of the immersion pyrometer employed (1,750° C.) so that later an optical pyrometer was brought into operation, and also that as the oxygen was additional to the normal air-blast of 2,700 cu. ft./ minute the total blast volume had been raised, and that this factor might be influencing the increased blowing loss.

In the next series of trials, the results from which are shown in Table II, the total blast volume was kept at 2,700 cu. ft./ minute and total oxygen contents of 30%, 40% and 60% were compared with normal air-blown heats in which it is assumed that 20·5% was present. With the higher percentages of oxygen the blowing losses were excessive, and it was realised that the rate of total blast would have to be reduced. However these trials showed that for pig-iron of the composition used the oxygen-enrichment was reducing the blowing time to about one-third of the normal time, and was raising the temperature increment to 500° C., as compared with the normal 300° C. Moreover no ferro-

TABLE II.—DETAILS OF HEATS BLOWN WITH A TOTAL RATE OF FLOW OF 2,700 CU. FT. PER MIN. OF OXYGEN-ENRICHED AIR

| Cast No. | Total % Oxygen | Rate of Air Blast (cu. ft./min.) | Rate of Oxygen Addition (cu. ft./min.) | Duration of blow (mins. secs.) | Vol. of Oxygen addition (cu. ft.) | Total Oxygen used: Theoretical oxygen | Total volume of Oxygen used (cu. ft.) | % of Total Oxygen derived from oxygen addition | Cupola metal Composition C | Si | Mn | Blown metal Composition C | Si | Mn | Cupola Metal Wt. Cwts. | Blowing Loss (%) | Temperature °C. Cupola metal (immersion) | Final Bath (Immersion) | Final Bath (Optical) | Increment | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 520 | 20·5 | 2700 | Nil | 15 | Nil | 1·47 | 8100 | Nil | 3·22 | 0·62 | 0·62 | 0·07 | 0·10 | 0·07 | 43½ | 7·5 | 1320 | 1620 | | 300 | |
| 525 | | | | 16 | | 1·50 | 8600 | ,, | 3·06 | 0·61 | 0·62 | 0·12 | 0·09 | 0·06 | 48 | 8·0 | 1320 | 1650 | | 330 | |
| 271 | | | | 13 | | 1·36 | 7100 | ,, | 3·07 | 0·66 | 0·47 | 0·13 | 0·09 | 0·02 | 43½ | 9·2 | 1290 | 1640 | | 350 | |
| 612 | | | | 14 | | 1·55 | 7500 | ,, | 3·06 | 0·59 | 0·53 | 0·10 | 0·07 | 0·04 | 40 | 8·2 | 1340 | 1620 | | 280 | |
| 739 | | | | 17 | | 1·43 | 9100 | ,, | 3·30 | 0·68 | 0·43 | 0·09 | 0·05 | 0·04 | 49 | 9·6 | 1350 | 1650 | | 300 | |
| 746 | | | | 18 | | 1·68 | 9700 | ,, | 2·91 | 0·78 | 0·57 | 0·09 | 0·01 | 0·06 | 49 | 8·5 | 1335 | 1660 | | 325 | |
| 980 | | | | 18 | | 1·61 | 9700 | ,, | 3·18 | 0·74 | 0·53 | 0·07 | 0·01 | 0·03 | 47 | 8·5 | 1320 | 1640 | | 320 | |
| Average | | | | 16·10 | | 1·51 | 8500 | ,, | 3·14 | 0·66 | 0·55 | 0·09 | 0·06 | 0·05 | 45½ | 8·5 | 1325 | 1640 | | 315 | |
| 530 | 30 | 2400 | 300 | 8·10 | 2700 | 1·39 | 6600 | 41 | 2·64 | 0·69 | 0·61 | 0·08 | 0·14 | 0·07 | 44 | 12·4 | 1340 | | 1750 | 410 | |
| 531 | | | | 8·56 | 2800 | 1·38 | 7100 | 39 | 3·04 | 0·71 | 0·46 | 0·11 | 0·11 | 0·09 | 43 | 12·7 | 1385 | | 1790 | 405 | |
| 534 | | | | 9·05 | 2800 | — | 7200 | 39 | 2·84 | 0·67 | 0·36 | — | — | — | 44 | 13·1 | 1395 | | 1790 | 395 | |
| 536 | | | | 7·30 | 2400 | 1·26 | 6000 | 40 | 2·76 | 0·61 | 0·29 | 0·09 | 0·07 | 0·06 | 44 | 6·8 | 1355 | | 1770 | 415 | |
| 537 | | | | 7·10 | 2300 | 1·18 | 5700 | 40 | 2·84 | 0·61 | 0·28 | 0·08 | 0·08 | 0·03 | 44 | 10·7 | 1380 | | 1800 | 420 | |
| Average | | | | 8·10 | 2600 | 1·30 | 6500 | 40 | 2·82 | 0·66 | 0·40 | 0·09 | 0·10 | 0·07 | 44 | 11·1 | 1371 | | 1780 | 409 | |
| 541 | 40 | 2000 | 700 | 6·43 | 4700 | 1·31 | 7400 | 64 | 3·07 | 0·80 | 0·36 | 0·08 | 0·13 | 0·08 | 45½ | 20·3 | 1350 | | 1830 | 480 | Oxygen approximately 35% for 1st 30 secs. |
| 542 | | | | 5·50 | 4300 | 1·30 | 6700 | 64 | 2·86 | 0·71 | 0·37 | 0·08 | 0·06 | 0·05 | 45 | 21·1 | 1370 | | 1855 | 485 | |
| 543 | | | | 4·58 | 3600 | 1·12 | 5600 | 64 | 2·74 | 0·51 | 0·37 | 0·07 | 0·09 | 0·06 | 46 | 21·3 | 1360 | | 1870 | 510 | |
| 547 | | | | 4·50 | 3800 | 1·18 | 5800 | 65 | 2·68 | 0·54 | 0·33 | 0·08 | 0·07 | 0·08 | 47 | 26·8 | 1360 | | 1850 | 490 | |
| 548 | | | | 5·15 | 4000 | 1·19 | 6100 | 65 | 2·77 | 0·42 | 0·42 | 0·08 | 0·06 | 0·05 | 46½ | 21·0 | 1355 | | 1820 | 465 | |
| Average | | | | 5·31 | 4100 | 1·23 | 6300 | 64 | 2·82 | 0·60 | 0·37 | 0·08 | 0·08 | 0·06 | 46 | 22·1 | 1359 | | 1844 | 485 | |
| 553 | 60* | 1600 | — | 4·09 | 7000 | | 8300 | 84 | 2·88 | 0·66 | 0·38 | — | — | — | 46 | 29·8 | 1370 | | 1880 | 510 | Oxygen manometer failed |

* The total blowing rate was 3,100, and not 2,700 cu. ft./min. for this cast.

silicon had been added to the oxygen-enrichment trials as compared with about 0·4% silicon which is normally added, so that the temperature would have been greater. Figure 2, shows in graphical form the effect of the oxygen-enrichment upon the blowing time, bath temperature, temperature increment and blowing loss for this uniform rate of total blast of 2,700 cu. ft/minute.

The next series of trials were made with a rate of flow for the total blast of 2,000 cu. ft./ minute, but owing to the fact that the air-blower was unable to deliver less than 1,600 cu. ft. of air per minute, the maximum concentration of oxygen which could be used was 35%. From the results of this series of trials, as given in Table III, it will be seen that the lower rate of total blast has resulted in a blowing loss of about 10% which is the normal loss without oxygen-enrichment.

During the course of the 30% oxygen heats it was noticed that whilst at the commencement of the blowing operation a vigorous carbon flame was obtained from the mouth of the converter, this flame later decreased for a period and then increased again rapidly just prior to the culmination of what is generally recognised as the

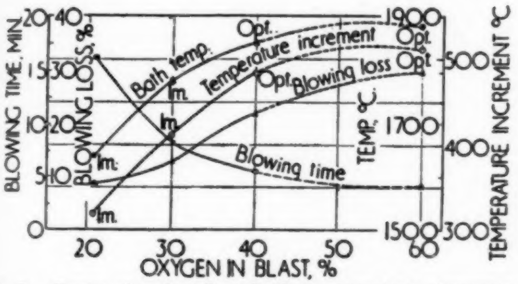



**Fig. 2.—Curve showing final bath temperature, temperature increment, blowing time and blowing loss, plotted against the oxygen concentration in the blast.**

carbon elimination. The appearance was as though there was insufficient oxygen present or as though the carbon combustion was temporarily being held in check. For this reason it was decided to run a series of heats in which the oxygen concentration was raised from 30–35% at about mid-way during the operation, i.e., after about 4 minutes. In this way the higher oxygen concentration was present when the bath appeared to be able to react with it readily, and the results (shown in Table IV) show how that the average blowing loss under these conditions are only 7·5%, which is an abnormally low figure.

The next series of trials were run under uniform conditions of a total blast of 2,000 cu. ft/ min. of 35% oxygen, but the blowing operation was interrupted before completion; namely, 2, 4 or 6 minutes after commencement and at the end of the blow, and samples of blown metal and its temperature were taken just as though the blow had been completed. After each heat had been interrupted the blow was completed but no further measurements were taken as it would not have been possible to have corrected for the unknown effect of the interruption itself upon the course of the heat. In this way a series of duplicated results for the condition of the bath at various stages of the blowing operation were obtained, and these results are given in Table V and plotted in graphical form in Fig. 3. These results confirm the previously visually observed lull in the carbon combustion, so that there is apparently a period in the middle of the operation during which the temperature and the carbon content remains unchanged, but as this observation leads to such an irregularity in the curves these are dotted and the individual results from the nine heats interrupted at 4 and 6 minutes are plotted as well as their average. Shortly previous to this investigation a similar study of interrupted blowing operations using air had been determined on the same plant, and for purposes of comparison these results are

TABLE III.—DETAILS OF HEATS BLOWN WITH OXYGEN-ENRICHED AIR AT A TOTAL RATE OF FLOW OF 2,000 CU. FT./MIN.

| Cast No. | Total % Oxygen | Rate of Air Blast (cu. ft./min.) | Rate of Oxygen addition (cu. ft./min.) | Duration of Blow (Min. secs.) | Vol. of Oxygen addition (cu. ft.) | Total volume of Oxygen used (cu. ft.) | % of Total Oxygen derived from Oxygen addition | Total Oxygen used / Theoretical Oxygen | Composition of Cupola Iron C | Si | Mn | Composition of Blown Metal C | Si | Mn | Wt. of Cupola Iron (Cwts.) | Blowing Loss % | Temperature (°C.) Cupola Metal (immersion) | Blown Metal (immersion) | Blown Metal (Optical) | Increment | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 558 | 30 | 1750 | 250 | 9·50 | 2700 | 6000 | 45 | 1·14 | 2·84 | 0·54 | 0·39 | 0·09 | 0·09 | 0·09 | 46 | 9·8 | 1345 | — | 1750 | 405 | |
| 663 | | | | 8·47 | 2400 | 5400 | 44 | 1·14 | 2·99 | 0·60 | 0·38 | 0·08 | 0·04 | 0·04 | 40 | 4·4 | 1330 | 1730 | | 400 | |
| 665 | | | | 7·45 | 2000 | 4800 | 42 | 0·94 | 3·34 | 0·54 | 0·39 | 0·08 | 0·13 | 0·03 | 40 | 11·8 | 1350 | (In excess of 1750) | | > 400 | |
| 671 | | | | 9·23 | 2600 | 5800 | 45 | 1·02 | 3·33 | 0·79 | 0·47 | 0·08 | 0·05 | 0·04 | 42 | 10·7 | 1340 | ,, | | > 410 | |
| 672 | | | | 9·18 | 2600 | 5800 | 45 | 1·09 | 3·17 | 0·76 | 0·55 | 0·08 | 0·13 | 0·09 | 42 | 12·3 | 1330 | ,, | | > 420 | |
| 723 | | | | 7·35 | 2000 | 4600 | 44 | 0·98 | 3·04 | 0·57 | 0·33 | 0·07 | 0·08 | 0·07 | 40 | 10·0 | 1330 | ,, | | > 420 | |
| 733 | | | | 7·43 | 2200 | 4900 | 45 | 1·02 | 3·28 | 0·49 | 0·39 | 0·08 | 0·09 | 0·10 | 38 | 9·2 | 1340 | ,, | | > 410 | |
| 747 | | | | 8·00 | 2200 | 5000 | 44 | 1·08 | 2·98 | 0·66 | 0·51 | 0·08 | 0·01 | 0·11 | 39 | 12·8 | 1370 | ,, | | > 380 | |
| 748 | | | | 7·24 | 2000 | 4600 | 44 | 0·99 | 2·94 | 0·75 | 0·48 | 0·12 | 0·08 | 0·12 | 40 | 10·0 | 1380 | ,, | | > 370 | |
| 755 | | | | 8·20 | 2300 | 5400 | 43 | — | — | — | — | 0·09 | 0·12 | 0·16 | 42 | 13·7 | 1350 | ,, | | > 400 | |
| 907 | | | | 9·15 | 2500 | 5800 | 43 | — | 3·12 | 0·76 | 0·37 | — | — | — | 44 | 9·5 | 1310 | 1735 | | 425 | Low temperature of cupola |
| 964 | | | | 10·10 | 2700 | 6300 | 43 | — | — | — | — | — | — | — | 44 | 9·8 | 1295 | 1675 | | 380 | |
| Average | | | | 8·38 | 2400 | 5300 | 45 | 1·07 | 3·10 | 0·65 | 0·40 | 0·08 | 0·08 | 0·08 | 41 | 10·2 | 1340 | — | — | -- | |
| 580 | 35 | 1650 | 350 | 9·20 | 3400 | 6300 | 54 | — | 2·94 | 0·69 | 0·36 | — | — | — | 42 | — | 1400 | | 1820 | 420 < | Blowing loss not recorded as some metal was left in converter |
| 589 | | | | 7·56 | 2900 | 5400 | 53 | 1·16 | 2·82 | 0·61 | 0·39 | 0·08 | 0·14 | 0·08 | 42 | 9·5 | 1400 | | 1810 | 410 | |
| 595 | | | | 8·05 | 3000 | 5600 | 53 | 1·05 | 2·96 | 0·57 | 0·41 | 0·08 | 0·11 | 0·09 | 45 | 11·5 | 1365 | | 1800 | 435 | |
| 596 | | | | 8·35 | 3200 | 5900 | 54 | 1·15 | 2·90 | 0·59 | 0·41 | 0·08 | 0·09 | 0·07 | 44 | 8·5 | 1380 | | 1810 | 430 | |
| 597 | | | | 8·00 | 2800 | 5500 | 51 | 1·18 | 2·70 | 0·46 | 0·33 | 0·09 | 0·14 | 0·11 | 44 | 11·7 | 1370 | | 1790 | 420 | First heat of the day |
| 150 | | | | 7·05 | 2500 | 4900 | 51 | — | 2·69 | 0·72 | 0·39 | — | — | — | 40 | 10·0 | 1250 | 1750 | | 500 | Very low cupola iron temperature |
| Average | | | | 8·10 | 2900 | 5600 | 52 | 1·16 | 2·85 | 0·61 | 0·38 | 0·08 | 0·12 | 0·09 | 43 | 10·3 | 1361 | | 1805 | 423 | |

TABLE IV.—DETAILS OF HEATS BLOWN WITH A TOTAL RATE OF FLOW OF 2,000 CU. FT./MIN. OF OXYGEN-ENRICHED AIR, BUT WITH % OXYGEN RAISED FROM 30% TO 35% AFTER 4 MINS.

| Cast No. | Duration of blow mins. secs. | Vol. of oxygen added cu. ft. | Total vol. of oxygen used cu. ft. | % of Total oxygen derived from oxygen addition | Total oxygen used: Theoretical oxygen | Composition of cupola metal: C | Si | Mn | Composition of blown metal: C | Si | Mn | Weight of cupola iron cwts. | Blowing loss % | Temperatures: Cupola metal °C. immersion | Final bath °C. immersion | Increment °C. | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 563 | 8·10 | 2,600 | 5,400 | 48 | 1·40 | 2·63 | 0·80 | 0·51 | 0·08 | 0·04 | 0·07 | 39 | 3·20 | — | 1,750 | | The blowing loss figures are obviously too low but indicate small loss |
| 564 | 8·30 | 2,800 | 5,900 | 47 | 1·43 | 2·70 | 0·63 | 0·47 | 0·13 | 0·08 | 0·12 | 39 | 3·90 | 1,390 | 1,740 | 350 | |
| 571 | 7·45 | 2,500 | 5,100 | 49 | 1·22 | 2·63 | 0·50 | 0·42 | 0·07 | 0·10 | 0·13 | 40 | 11·20 | 1,335 | 1,710 | 375 | |
| 572 | 8·44 | 2,700 | 5,900 | 46 | 1·41 | 2·65 | 0·61 | 0·43 | 0·08 | 0·15 | 0·13 | 40 | 5·10 | 1,345 | 1,720 | 375 | |
| 573 | 11·10 | 3,200 | 7,100 | 45 | — | — | — | — | — | — | — | 40 | 8·10 | 1,340 | 1,740 | 400 | First heat of day |
| 574 | 7·43 | 2,600 | 5,800 | 45 | 1·28 | 2·84 | 0·71 | 0·39 | 0·10 | 0·17 | 0·08 | 40 | 13·70 | 1,380 | 1,730 | 350 | |
| Av'age | 8·40 | 2,730 | 5,870 | 46·5 | 1·36 | 2·69 | 0·65 | 0·44 | 0·09 | 0·11 | 0·11 | 39⅔ | 7·53 | 1,360 | 1,730 | 370 | |

reproduced in graphical form in Fig. IV. It will be seen that there is a slight tendency here also for a lull in the carbon reaction. It was observed that with oxygen-enrichment the end-point of the blow was sharper and easier to detect than with the normal air-blowing operation.

The last series of trials were made by using a total blowing rate of 2,000 cu. ft./ min. of 30% oxygen into a liquid iron charge which had been melted in a cupola from steel scrap only. In this way the liquid iron after de-sulphurising had an average temperature of only 1,315° C. and an average silicon content of only 0·16, and yet the blowing operation conferred a temperature increment of 325° C., which enabled it to be cast satisfactorily. The results from these trials are given in Table VI.

### Properties of the Finished Steel

After a careful examination of the chemical composition, physical condition and mechanical properties of typical specimens of the finished steel obtained from these trails the authors are satisfied that the steel so produced was in no way inferior to that normally produced. The carbon content of the blown metal was on an average the same as that normally obtained, but a most important point observed was that the carbon content of the steel from the oxygen-enriched heats was the more consistent. A statistical study was made of 48 oxygen-enriched heats and compared with a similar number blown normally with air in the period immediately prior to the trials, and the results are as follows :

| | Normal Air-blown | Oxygen-enriched |
|---|---|---|
| Average carbon content % .. .. .. .. .. | 0·082 | 0·085 |
| Range of carbon contents % .. .. .. .. | 0·03/0·13 | 0·06/0·13 |
| Number of readings outside the range 0·06/0·10% .. .. .. .. .. .. .. .. .. | 11 | 4 |
| Standard deviation % C. .. .. .. .. .. | 0·022 | 0·014 |

The following determinations of the gas content of the finished steel were made by the vacuum-fusion method :

| Cast No. | % Oxygen in Blast | Temperature of blown metal ° C. | % $O_2$ | % $H_2$ | % $N_2$ |
|---|---|---|---|---|---|
| 536 | 30 | 1770 | 0·005 | 0·00006 | 0·004 |
| 547 | 40 | 1850 | 0·005 | 0·00004 | 0·007 |

from which it will be seen that the oxygen contents are normal, the hydrogen contents are rather low and the nitrogen contents normal, excepting that by reason of the high temperature of Cast 547, a somewhat higher nitrogen content might have been expected. If these results are typical it would therefore appear that the gas content of the steel produced is favourable and certainly lower than with bottom-blown operation.

The sulphur content of most of the steels produced during this period were higher than normal due to the necessity of using unsuitable scrap, and though this had

TABLE V.—DETAILS OF HEATS WHICH WERE INTERRUPTED BEFORE THE BLOW WAS COMPLETED (2,000 CU. FT./MIN. of 35% OXYGEN-ENRICHED AIR)

| Cast No. | Duration of blow before interruption mins. | Total oxygen used*: Theoretical oxygen | Cupola metal Composition: C | Si | Mn | Composition of bath at interruption: C | Si | Mn | Weight of cupola metal cwts. | Cupola metal temp. immersion | Bath temperature: °C. (optical) | °C. (immersion) | Temperature increment (°C.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 602 | 2·00 | 3·30 | 3·05 | 0·76 | 0·41 | 2·89 | 0·53 | 0·31 | 44 | 1,375 | | 1,435 | 60 |
| 603 | | 2·83 | 2·98 | 0·69 | 0·36 | 2·82 | 0·36 | 0·21 | 44 | 1,365 | | 1,440 | 75 |
| 604 | | 2·73 | 2·80 | 0·56 | 0·32 | 2·62 | 0·25 | 0·18 | 44 | 1,320 | | 1,370 | 50 |
| 614 | | 1·50 | 3·14 | 0·98 | 0·38 | 2·60 | 0·65 | 0·27 | 38 | 1,370 | | 1,485 | 105 |
| 617 | | 3·05 | 2·86 | 0·60 | 0·36 | 2·68 | 0·27 | 0·18 | 38 | 1,380 | | 1,490 | 110 |
| Average | | 2·68 | 2·97 | 0·72 | 0·37 | 2·72 | 0·41 | 0·23 | 41⅗ | 1,363 | | 1,443 | 80 |
| 629 | 4·00 | 1·15 | 3·14 | 0·85 | 0·37 | 1·72 | 0·28 | 0·15 | 40 | 1,335 | | 1,640 | 305 |
| 630 | | 1·02 | 3·11 | 0·62 | 0·37 | 1·40 | 0·15 | 0·13 | 40 | 1,350 | | 1,630 | 280 |
| 644 | | 0·95 | 3·30 | 0·68 | 0·38 | 1·50 | 0·23 | 0·17 | 42 | 1,360 | | 1,590 | 230 |
| 645 | | 0·96 | 3·30 | 0·59 | 0·29 | 1·48 | 0·21 | 0·15 | 42 | 1,340 | | 1,610 | 270 |
| 646 | | 0·99 | 3·14 | 0·47 | 0·32 | 1·30 | 0·24 | 0·16 | 42 | 1,340 | | 1,620 | 280 |
| Average | | 1·01 | 3·20 | 0·66 | 0·35 | 1·48 | 0·20 | 0·15 | 41⅕ | 1,343 | | 1,623 | 280 |
| 978 | 6·00 | 1·43 | 3·22 | 0·50 | 0·33 | 1·59 | 0·15 | 0·11 | 46 | 1,335 | | 1,650 | 315 |
| 980 | | 1·14 | 3·30 | 0·61 | 0·38 | 1·25 | 0·18 | 0·21 | 46 | 1,310 | | 1,620 | 310 |
| 39 | | 1·77 | 3·15 | 0·72 | 0·56 | 1·84 | 0·16 | 0·22 | 42 | 1,300 | | 1,590 | 290 |
| 40 | | 1·77 | 2·82 | 0·72 | 0·62 | 1·48 | 0·24 | 0·20 | 42 | 1,315 | | 1,600 | 285 |
| Average | | 1·42 | 3·12 | 0·64 | 0·48 | 1·54 | 0·18 | 0·18 | 44 | 1,315 | | 1,615 | 300 |
| 585 | 9·36 | 1·33 | 3·03 | 0·69 | 0·39 | 0·10 | 0·29 | 0·11 | 44 | 1,395 | 1,780 | | 385 |
| 589 | 7·56 | 1·23 | 2·82 | 0·61 | 0·39 | 0·08 | 0·14 | 0·08 | 42 | 1,400 | 1,810 | | 410 |
| 595 | 8·05 | 1·11 | 2·96 | 0·57 | 0·41 | 0·08 | 0·11 | 0·09 | 45 | 1,365 | 1,800 | | 435 |
| 596 | 8·35 | 1·23 | 2·90 | 0·59 | 0·41 | 0·08 | 0·09 | 0·07 | 44 | 1,380 | 1,810 | | 430 |
| 597 | 8·00 | 1·25 | 2·70 | 0·46 | 0·33 | 0·09 | 0·14 | 0·11 | 44 | 1,370 | 1,790 | | 420 |
| Average | 8·26 | 1·23 | 3·00 | 0·64 | 0·38 | 0·08 | 0·15 | 0·09 | 44 | 1,382 | 1,798 | | 416 |

* In this table it has been assumed that no iron has been oxidised from the bath.

TABLE VI.—DETAILS OF HEATS BLOWN FROM ALL-STEEL-SCRAP CHARGED TO THE CUPOLA; USING A RATE OF FLOW OF 2,000 CU. FT./MIN. OF 30% OXYGEN-ENRICHED AIR INTO THE SIDE-BLOWN CONVERTER

| Cast No. | Duration of blow (mins. secs.) | Vol. of oxygen addition (from gauge) (cu. ft.) | Total vol. of oxygen used (cu. ft.) | Total oxygen used / Theoretical oxygen | % of total oxygen derived from oxygen addition | Composition cupola metal before desulphurising | | | | | Composition cupola metal after desulphurising | | | | | Composition blown metal | | | | | Wt. of cupola iron (cwt.) | Blowing loss % | Temperature (°C.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | C | Si | Mn | S | P | C | Si | Mn | S | P | C | Si | Mn | S | P | | | Cupola metal | Blown metal | Increment |
| 706 | 8·40 | 2,300 | 5,300 | 0·98 | 43 | — | — | — | — | — | 3·08 | 0·24 | 0·25 | 0·044 | 0·044 | 0·08 | 0·04 | 0·08 | 0·042 | 0·050 | 48 | 5·20 | 1,310 | — | — |
| 790 | 8·12 | 2,200 | 5,100 | 1·07 | 43 | — | — | — | — | — | 2·78 | 0·23 | 0·22 | 0·057 | 0·039 | 0·10 | 0·05 | 0·10 | 0·055 | 0·049 | 46 | 14·70 | 1,320 | 1,630 | 310 |
| 928 | 7·20 | 2,000 | 4,500 | — | 44 | — | — | — | — | — | 2·78 | 0·16 | 0·20 | 0·051 | 0·013 | — | — | — | — | — | 48 | — | 1,300 | 1,640 | 340 |
| 968 | 9·45 | 2,500 | 5,900 | — | 43 | 2·66 | 0·30 | 0·44 | 0·132 | 0·037 | 2·97 | 0·10 | 0·28 | 0·054 | 0·027 | — | — | — | — | — | 48 | 7·80 | 1,320 | — | — |
| 969 | 7·15 | 2,000 | 4,500 | — | 44 | 2·99 | 0·16 | 0·27 | 0·106 | 0·037 | 2·86 | 0·06 | 0·24 | 0·051 | 0·033 | — | — | — | — | — | 50 | 7·00 | — | — | — |
| 25 | 7·10 | 2,000 | 4,500 | — | 44 | 3·00 | 0·29 | 0·28 | 0·105 | 0·076 | — | — | — | — | — | 0·10 | 0·01 | 0·08 | 0·039 | 0·054 | 40 | 11·20 | 1,325 | — | — |
| Average | 8·04 | 2,200 | 5,000 | 1·00 | 44 | 2·88 | 0·28 | 0·33 | 0·114 | 0·050 | 2·89 | 0·15 | 0·23 | 0·051 | 0·031 | 0·09 | 0·03 | 0·09 | 0·044 | 0·051 | 46 | 9·18 | 1,315 | 1,635 | 325 |

the effect of decreasing the tensile properties of the steels it is in no way connected with the oxygen-enrichment. Likewise the use of higher proportions of steel scrap has led to higher final phosphorus contents and steps are being taken to reduce the phosphorus content.

Examination of polished sections prepared from the steels showed that the micro-structure was not affected in the slightest by the use of oxygen. In the "as cast" condition it consisted of coarse pearlite and ferrite distributed in a normal manner. After the heat-treatment, in which the steel was soaked for 4 hours at 950° C. followed by air cooling, the structure of pearlite and ferrite was normal. The treatment as usual had a refining action on the grain size which was then about 6 on the McQuaid-Ehn scale.

As stated previously in this paper, the earlier method of de-oxidation was by means of aluminium rabbled into the bath of blown metal before the addition of alloys, although this practice was altered later and calcium-silcon-manganese was used as a final de-oxidiser in the ladle, no aluminium being added. In the former process the amount of aluminium added (6½-lb. per ton of steel) was sufficient to give satisfactory distribution of the inclusions, which consisted chiefly of small irregular-shaped sulphides together with some particles of alumina. The use of calcium-silicon-manganese alloy (2-lb. per ton of steel) gave comparatively small inclusions nearly all of which were globular and distributed at random through the steel. They consisted almost entirely of complex non-glassy iron-manganese silicates and of iron-manganese-sulphides. A few of the larger inclusions showed signs of a duplex structure but this was not the general case.

With both methods of de-oxidation the inclusion count showed that the total amount of inclusions was certainly no more than occurred in steel produced at this plant without the addition of oxygen to the blast.

Thus the micro-structure and the quality of the non-metallic inclusions were almost exactly the same, and the quantity of inclusions was certainly no greater with the use of oxygen-enriched air than would be produced by the normal method of operation.

Tensile tests have been carried out on many of the casts of steel blown with oxygen-enriched air. The whole of the results are too numerous to detail here but Table VII shows the tensile properties of a few typical heats. It will be noted that the figures shown in this table cover almost the full range of oxygen-enrichments described in this report, and were selected for that reason.

## Effect on Converter Lining

Most of the reports from work carried out on bottom-blown plants clearly indicate that one of the main problems affecting the success of the process is the very extensive wear encountered, particularly, in the region of the tuyeres. The work carried out in Russia by Kondakov gave tuyere life of only one heat and little success was achieved in finding suitable refractories to overcome the difficulty although various methods were tried. There was some speculation therefore when this work was commenced as to how side-blown converter linings would withstand the highly-oxidising high-temperature conditions.

These experiments have now been going on for several months and in many cases at least half of the number of heats blown per lining have been with oxygen-enriched air mostly of 30% or 35% oxygen, and in no case has a lining failed due to oxygen-enrichment, and moreover there has been no noticeable decrease in the average life of the linings. When high percentages were used at the greater blast velocities increased tuyere wear was noted, and using 40% oxygen the wear appeared to be in the region of ¼ in–½ in. per blow. This would give an expectation of life of 26–30 heats per set of tuyeres, which is not unreasonable.

Although the final temperature is much higher the blowing time is shorter so that the main bulk of the refractory probably does not reach a very high temperature. It is hoped at a later date to insert thermocouples in the lining to study the temperature gradients and

TABLE VII.—MECHANICAL PROPERTIES OF STEELS

| Cast No. | % Total Oxygen | Composition of Steel | | | | | Ultimate Tensile Strength Tons/sq. in. | Yield Point Tons/sq. in. | Elongation % on 2 in. | Reduction in Area % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | C | Si | Mn | S | P | | | | |
| 531 | 30 | 0·26 | 0·51 | 1·66 | 0·055 | 0·054 | 35·24 | 19·24 | 25 | 35 |
| 542 | 40 | 0·22 | 0·53 | 1·17 | 0·050 | 0·061 | 33·12 | 18·80 | 31 | 45 |
| 581/3 | 30 / 35 | 0·18 | 0·40 | 1·11 | 0·085 | 0·060 | 33·56 | 17·52 | 31 | 50 |
| 604 | 35 | 0·27 | 0·42 | 1·36 | 0·068 | 0·050 | 37·80 | — | 27 | 37 |
| 783 | 30 / 35 | 0·24 | 0·34 | 1·45 | 0·051 | 0·045 | 40·80 | — | 25 | 37 |
| 790 | 30 | 0·24 | 0·37 | 1·42 | 0·044 | 0·044 | 37·52 | — | 26 | 42 |

fluctuations on the lines laid down in the First Report on Side-Blown Converter Refractories.

Additions of sand were made between heats and also to the surface of the metal before blowing.

## Blowing Loss and Theoretical Oxygen Requirements

While the term " blowing loss " is quite familiar to users of converter plants, some explanation of its meaning may be necessary for the benefit of those who are not intimately connected with such plants. It will be appreciated from the text of the report that although this figure varies under different operating conditions, the normal blowing loss, under standard conditions at the Works at which the experiments were undertaken, is approximately 10%. This figure represents the average for side-blown converter plants in this country, most values being between 8% and 14% according to the method of operation and design of the plant.

Blowing loss results from two causes; chemical and mechanical. Chemical loss is due to the oxidation of the elements, carbon, silicon, manganese and iron. The oxidation of carbon, silicon and manganese is dependent on the original composition of the cupola metal and accounts for the loss of between 4% and 5%. The oxidation of iron is governed partly by the composition of the cupola metal, and also by the operating temperature and the length of the blow, and probably amounts to a further $1\frac{1}{2}$%, as estimated from the iron oxide normally found in the slag.

The mechanical loss is due to the ejections of reactive slag and metal during the blow, and accounts for the remainder of the blowing loss. This loss is controlled to some extent by the design of the converter, and the volume and pressure of air employed, and any reduction of this loss would be an obvious improvement in the steel-making process. The higher blowing losses, with higher blowing rates, are presumably accounted for by this mechanical loss. It was observed that the density of fume was greater with oxygen-enrichment, and measures to reduce this fume are therefore being considered.

A fuller discussion on blowing loss appears in the First Report of the Side-Blown Converter Practice Sub-Committee, of the Steel Castings Research Committee, and was published in the " Journal of the Iron and Steel Institute " for January, 1947.

In order to estimate the efficiency with which the total oxygen entering the furnace has entered into the chemical reactions, the theoretical oxygen required to oxidise the measured losses during the blowing operation of carbon to carbon dioxide, silicon to silica, and manganese to manganous-oxide have been calculated from their stoichiometric equivalents, in terms of cubic feet of oxygen. It has then been assumed that 1·5% of iron has been oxidised and is necessarily retained in the slag as ferrous oxide, and the (stoichiometric) equivalent of this has been added to give a figure for the total theoretical oxygen required. In the tables of results, this figure has been divided into the actual oxygen consumption to give a measure of inefficiency or excess oxygen consumption. It will be seen that 50% or more excess of oxygen may normally be used, but that the excess required is markedly reduced by oxygen-enrichment. Thus, as might be expected, reduction in the nitrogen content of the blast leads to a more efficient utilisation of the total oxygen blown into the furnace, or to a better " oxygen-balance." For the interrupted heats, since oxidation of the carbon and silicon was incomplete it is assumed that the iron loss by oxidation was neglible.

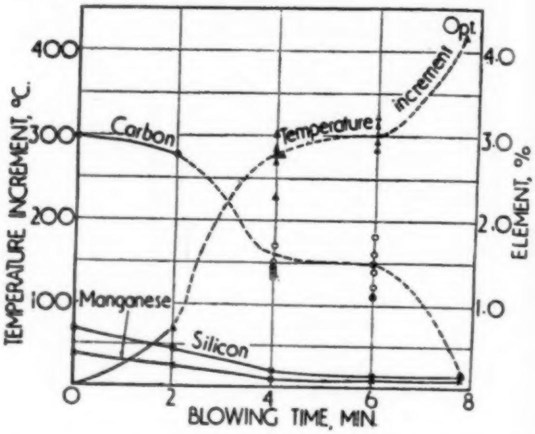



**Fig. 3.—Graph showing the chemical changes of the bath and temperature increment, using oxygen-enriched air containing 35% oxygen, in a side-blown converter.**

## Discussion of Results

After experience now with over 200 oxygen-enriched heats the authors are satisfied that even a moderate degree of oxygen-enrichment applied with little or no modification to existing converter units can lead to an improvement in steel-making practice. The fact that a closer degree of control can be gained in this steel-making operation is a feature of great value, which should favourably influence the future application of the side-blown converter. The authors would not put undue significance upon the shortening of the blowing operation for the average foundry, where melting capacity is generally adequate, but they would suggest that larger furnaces of this type might, with oxygen-enrichment, be employed for bulk ingot steel production, especially in basic-lined vessels. At the same time the significance of higher steel temperatures to a foundry only requiring small quantities of steel intermittently is obviously an attractive feature, especially where thin-section castings are being made and greater fluidity is desired.

The fact that under normal operating conditions with air-blowing, such a large excess of air was passed through a side-blown converter has not been reported before, as far as the authors are aware, and the fact that oxygen-enrichment so markedly increases the efficiency of the oxygen reactions is an additional factor of merit. This is in accord with the higher oxygen efficiency reported by Kondakov* for bottom-blown converters. The apparent reason for this is that normally the high blowing rate necessary for reasonably rapid completion of the heat is too high for complete chemical reaction with the bath. This point is intimately linked up with the blowing loss; normally the blowing loss is the dominating factor limiting output, but by reducing the rate of nitrogen passage through the converter the blowing loss can be substantially reduced, as shown by these trials. Clearly, therefore, blowing loss is not so much dependent upon rate of oxidation as upon rate of efflux of gas from the converter, though in this connection

* V. V. Kondakov: *Bull. de l'Acad. des Sci. de l'U.S.S.R.*, 1946, **10**, 1401.

it should be pointed out that carbon monoxide (or dioxide) has also of necessity to pass out as a gas from the vessel, and with the trials made in which the oxygen content was varied to stabilise the carbon reaction the blowing loss was abnormally low.

It will be evident that substantial oxygen additions are necessary to raise the oxygen content of the blast

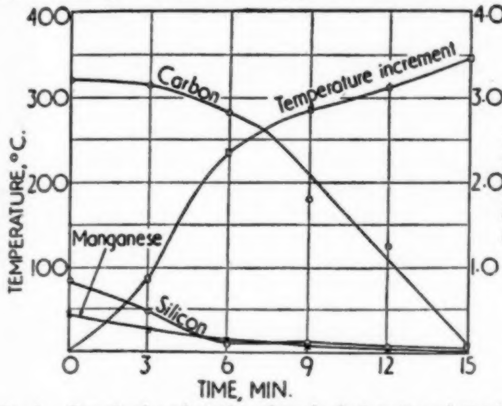



**Fig. 4.—Graph showing the chemical changes of the bath and temperature increment, during normal side-blowing operations.**

moderately (e.g., 25% of the oxygen is added to make about 25% oxygen blast and 50% of the oxygen is added to make a 35% oxygen blast) whereas relatively little extra oxygen is necessary to raise the content of the more enriched blasts (e.g., 60% oxygen blast already has nearly 85% of its oxygen added.) Since moreover, the oxygen efficiency is likely to be higher for higher percentages the controlled supply of oxygen of tonnage quality and without any air would appear to be a likely future development. This would, of course, dispense with all blowing equipment, but it might require modifications to the converter shape and especially to the number and dimensions of the tuyeres. Such trials are now in hand at the same works.

In normal side-blown converter practice it is found that the carbon oxidation only proceeds with rapidity when the bath has reached a temperature of over 1,400° C. and it is a generally accepted idea that the function of silicon is to "kindle" the bath to the requisite temperature. This phenomenon is well shown in Fig. 4. However, with oxygen-enrichment and in the absence of silicon the carbon combustion proceeds quite rapidly even at low temperatures. The probable explanation of this is merely that the oxygen-enrichment has so accelerated the carbon combustion that it is sufficiently high even at the low temperatures. Theoretically it should proceed throughout the possible temperature range, but elevation in temperature should be favourable for the combustion.

After the carbon combustion has proceeded to about half-way and with a temperature increment of 200–300° the carbon reaction and temperature tend to become stationary for a period. This is a remarkable fact, which it is not easy to explain (see Fig. 3.). As has been pointed out the same effect to a slight extent (see Fig. 4) can be seen from the normal air-blown heats, though it must be admitted that no significance had previously attached to this slight effect. One explanation of this is that at this stage the slag passages through a viscous and sluggish condition so that oxidation is hindered, and the great variation in the oxygen efficiencies at the different stages of the blow (Table V) lends support to this idea, as does also the fact that raising the oxygen content at the sluggish period (see Table IV) results in a poor oxygen efficiency.

Probably by reason of the high temperature attained by these trials the silicon is not so completely oxidised out of the bath, or alternatively that there is some reversion of silicon back to the bath from the silica of the slag. The average effect would appear to be an increment of 0·05% of silicon, which may mean some economy in the quantity of de-oxidants to be added.

A consideration of the economic aspects of oxygen-enrichment is a rather complex matter. On the one side there is the added cost of adding 1,000 to 2,000 cu. ft. of oxygen per ton of steel, but on the other side there is a series of factors of value varying with differing works requirements; and some of which, such as enhanced fluidity, higher output or shorter working day, which may be of over-riding importance. However, from the saving of raw materials, such as cupola fuel, pig-iron and silicon, as well as from the reduction of the blowing loss commensurate economies can be seen, especially if, as is probable, the cost of oxygen of suitable quality can be brought down.

As yet the side-blown converter process is used predominantly for making carbon steel and manganese steel (the manganese being added in molten form), but the higher temperatures obtainable with oxygen-enrichment open up the possibility of making substantial cold additions to the blown carbon-steel base charge, so that it should be practicable to make high alloy steels by this process. Trials are shortly to be made upon this proposal.

## Conclusions

It is concluded that oxygen-enrichment of the side-blown converter is likely to be widely applied in the future on account of the following technical advantages which have been demonstrated in this Report, namely :—

(1) A higher steel temperature is possible with its attendant advantages in the foundry of increased fluidity and reduced skulling loss.

(2) A shorter blowing cycle is possible, thus permitting a higher steel output from a given plant or alternatively a smaller plant for a given output.

(3) A lower molten iron temperature can be accepted thus permitting some fuel economy in the cupola.

(4) An all-scrap charge may be used in the cupola, thus allowing of a reduced pig-iron consumption.

(5) The elimination of the need for any ferro-silicon addition during cupola melting or during the blowing operation.

(6) A reduction in the blowing loss.

(7) An easier control of the end-point and a proven more consistent final composition.

From experience from over 200 heats which have been oxygen-enriched the authors are of the opinion that the side-blown converter with oxygen-enrichment is likely to be increasingly used in foundries not only for carbon and manganese steels but also that with modifications in design in the light of the altered aerodynamic conditions inside the converter it could be used, probably with a basic lining and in larger units, for bulk ingot steel production.


## Acknowledgements

The authors wish to record their grateful thanks to Mr. A. Catton and Mr. D. E. Catton in whose works this

investigation was performed, for their interest and encouragement and for permission to publish the results. Also to all members of the Steel Plant, Foundry, Laboratory, Maintenance and Drawing Offices staff of Messrs. Catton & Co., Ltd., for all the assistance given. They also acknowledge willing assistance of staff of the British Iron and Steel Research Association, especially to Messrs. Langner and Parsons and Mr. G. E. Speight of the Research and Development Department of the United Steel Co., Ltd.

The authors also acknowledge the very great help and co-operation of the British Oxygen Co., Ltd.

# Production Engineering Research Association

## Annual General Meeting at Staveley Lodge

A CONSIDERABLE number of representatives from member-firms attended the recent Annual General Meeting of the above Association. They were also invited to make a tour of the workshops, laboratories and offices, where demonstrations of practical work and displays of various groups of photographs illustrating applications of research, stages in building development at Staveley Lodge, etc., had been arranged.

At the meeting, Mr. A. Siddall, M.I. Mech. E., and Mr. H. Townsend, M.I.P.E., were elected as the two representatives of ordinary members to the Council. It was also announced that Sir Lionel Kearns, C.B.E., M.A., was elected Chairman of Council. In the course of the meeting the Chairman presented the report of Council covering the period since the second annual meeting of the Association held last September, some of the more important features indicate the progress being made by this young Association.

### Third Annual Report

The main work of reconstruction and adaptation of Staveley Lodge and outbuildings was completed early in 1948 after various difficulties and delays. The Technical Committee, set up by the Council in September last, meets regularly and, with the assistance of sub-committees and panels, plans and supervises the research activities of the Association. The scope of these activities is indicated by the 1948 research programme, which includes :

1. Performance of Machine Tools, including vibration tests, deflection tests, alignment tests, efficiency tests and production tests for roughing and finishing operations.
2. The effect of Cutting Fluids upon the efficiency of various machining operations, such as the turning, milling, grinding and drilling of various metals.
3. Investigations on behalf of the Ministry of Supply into the machinability and formability of selected materials when subjected to various cutting and forming processes.
4. Private investigations as requested by individual members.

These particular researches have been given priority in the 1948 Research Programme because of their basic importance to the industry as a whole. Satisfactory progress is being made with these investigations, standard machines, on loan from member-firms, being used for the machine tool investigations. Difficulties have been encountered, however, in the permanent equipping of the workshops and laboratories with the particular types of machine tools necessary for the full implementation of research programmes. The Industrial Grants Committee of the Department of Scientific and Industrial Research has been approached regarding a special grant of £25,000 for the purchase of machine tools and equipment from the Ministry of Supply surplus stores, and the Chairman announced that this grant had been approved.

The membership of this Association now exceeds 160, and assures an annual recurring income exceeding £41,000 from subscriptions and the D.S.I.R. Grant. Increasing membership and receipts from Ministry of Supply and private investigations are estimated to increase the total income of the Association for 1948 to approximately £55,000.

The present financial position is satisfactory, but the Council feels that the future extension of research and of information services throughout industry must be dependent on the number of firms joining the Association. As there are approximately 10,000 firms in Great Britain which would benefit by these researches, members were asked to use their influence in making known the potentialities of the Association and to introduce as many new members as possible.

## Inter-Service Metallurgical Research Council

THE Admiralty and Ministry of Supply have set up an Inter-Service Metallurgical Research Council to advise them on metallurgical problems of importance to the Services. This Council will provide for the interchange of ideas on metallurgical problems common to the different Services, and avoid overlap between their research programmes. It should also ensure that balance is maintained between fundamental and *ad hoc* research, and that the long term research necessary for the provision of new alloys is embarked upon.

The Research Council includes representatives of the Admiralty and Ministry of Supply, and a number of distinguished metallurgists from the Universities, Industry, and other Government Departments. The independent members are:—Professor L. Aitchison, D.Met., B.Sc., F.R.I.C., F.I.M. (Chairman) ; Professor E. N. da C. Andrade, Ph.D., D.Sc., F.R.S. ; Professor G. Wesley Austin, O.B.E., M.A., M.Sc., F.I.M. ; Mr. G. L. Bailey, M.Sc., F.I.M. ; Dr. R. W. Bailey, D.Sc. (Eng.), Wh.Sc., M.I.Mech.E. ; Mr. H. H. Burton, F.I.M. ; Dr. W. Hume-Rothery, M.A., D.Sc., Ph.D., F.I.M., F.R.S. ; Dr. H. Moore, C.B.E., Ph.D., D.Sc., F.R.I.C., F.Inst.P., F.I.M. ; Mr. A. J. Murphy, M.Sc., F.I.M. ; Mr. D. A. Oliver, M.Sc., F.Inst.P., F.I.M. ; Dr. C. J. Smithells, M.C., D.Sc., F.I.M. ; Dr. C. Sykes, D.Sc., Ph.D., F.Inst.P., F.I.M., F.R.S. ; and Dr. W. H. J. Vernon, O.B.E., B.Sc., Ph.D., D.Sc., D.I.C., F.R.I.C., F.I.M. ; the Secretary is Mr. A. H. Waterfield of the Ministry of Supply.

# Corrosion of Iron and Steel

## Atmospheric Protection and Marine Fouling

*The investigation of corrosion problems being a long and complex business, it is necessary to take stock of the situation from time to time, and the discussions arranged by the Iron and Steel Institute and the British Iron and Steel Research Association serve a very useful purpose in this respect. In this report are presented summaries of papers on protection against atmospheric corrosion, anti-fouling compositions and cementiferous paints, and the discussion on them at a recent meeting.*

AT a recent one-day Meeting arranged jointly by the Iron and Steel Institute and the British Iron and Steel Research Association several papers concerned with the protection of steel against atmospheric corrosion and marine fouling were discussed.

The morning session, under the chairmanship of Mr. T. M. Herbert, Deputy Chairman of the Corrosion Committee and Chairman of the Protective Coatings Sub-Committee, opened with a discussion of the First Report of the Methods of Testing (Corrosion) Sub-Committee*, presented by Dr. J. C. Hudson.

### Accelerated Corrosion Testing

As a result of the extensive use of sheet steel in the construction of pre-fabricated houses, the Ministry of Works became interested in the question of the protection of such material. At the suggestion of the Ministry, the British Standards Institution, in November, 1944, set up Technical Committee ISE/28, " Standards of Protection for Iron and Steel Used in Building Construction," to deal with the problem. After devoting some time to a consideration of the types of coating likely to be suitable, this Technical Committee issued some general recommendations for the guidance of industry†. It was apparent, however, that the best way to achieve the desired end was not to lay down hard and fast rules as to the protective schemes themselves, but to specify the minimum performance acceptable. As the investigation of testing methods was not within the province of the B.S.I. Committee, this part of the work was handed over to what is now the Methods of Testing (Corrosion) Sub-Committee of the British Iron and Steel Research Association.

The object of the report is to present the results of the work undertaken by the Sub-Committee in order to decide on a suitable short-time test for schemes of protection applied to light gauge steel. The main outcome of the investigations was that the Sub-Committee was able to advise B.S.I. Technical Committee, I.S.E./28, regarding the preparation of a standard performance test, and that, as a result, the latter was able to compile Provisional British Standard 1391 : 1947—" Performance Test for Protective Schemes Embracing Stoving Paints Used in the Protection of Light-Gauge Steel and Wrought Iron against Corrosion." This specification has purposely been made provisional as further work and experience may lead to changes on revision. It is impossible in the space available to do justice to the detailed information contained in the report; readers especially interested should consult the original, but in doing so they should bear in mind that the work was undertaken primarily to check various accelerated corrosion tests and not to investigate the behaviour of a number of protective schemes.

The extensive nature of the experimental work may be judged from the fact that each of 16 different protective schemes, together with a set of unprotected specimens, was tested by each of 9 different methods. The protective schemes included painting, with and without phosphate treatment and metal coatings, with and without painting. In the case of zinc coating, some specimens were phosphated before painting. The painting in all cases comprised one coat of stoving paint, applied by hand and stoved under standardised conditions. The testing methods included an atmospheric exposure test at the B.I.S.R.A. Corrosion Laboratory, Birmingham, and eight accelerated tests using humidity, salt-spray, sulphur dioxide and ultra-violet light in various combinations. The sheet test pieces had "standard damage," on the bottom half, consisting of a circular groove, a scratch and an impact dome caused by a standard hammer blow. As a result of comparison of the accelerated tests with the atmospheric weathering tests, after 1·5 years, it was decided that a salt-spray test devised by the Armament Research Department was the most promising short-time test, and this forms the basis of B.S.I. Provisional Specification 1391 : 1947. It was, of course, necessary to establish the reproducibility of the test and for this purpose, sets of test-pieces were made up and tested in various laboratories, the results showing substantially good agreement. Reasonable standards of performance in this test for protective schemes embracing single coats of stoving paints, applied over phosphated or non-phosphated steel, were determined by means of tests on typical industrial finishes of this type.

In introducing the report, Dr. Hudson commented on the importance of film thickness and on the tester used for its measurement. This was an A.R.D. instrument developed for metallic coatings on steel ; for use on paint a layer of tin-foil of known thickness had to be interposed to prevent damage to the paint. The Provisional B.S. 1391 : 1947 was good as far it went, but it dealt only with phosphated and stove-painted specimens ; Schemes B and C of the specification, including a metallic coating of unspecified and specified thickness respectively, might form the basis of future work by the Sub-Committee.

Dr. Clarke (Armament Research Department), commenting on the unanimity of the Sub-Committee, claimed that a reasonable performance test, with legitimate bounds to its use, had been attained. The object was to sort out poor protective schemes from good ones, to eliminate the " mud and water " type of paint or paint not covering the surface, or adhering improperly.

Mr. E. J. Bond (Goodlass Wall & Co.) was surprised that an anti-corrosion pigment was not included in the

* *J.I.S.I.*, April, 1948.

† P.D. 420 " Recommendations on Methods of Protection against Corrosion for light-Gauge Steel and Wrought Iron used in Permanent Building Construction."

primer, but Dr. Hudson pointed out that they were aiming at a relative test and not the absolute corrosion protection.

MR. F. FANCUTT (Railway Executive—London Midland Region) advocated caution in the interpretation of the results of accelerated tests. He wondered if acceleration to five days, however, was excessive from the user angle. Mr. Fancutt was anxious that tests should be practical in application and suggested the extension of the experiments to include the testing of different coatings, surfaces and film thicknesses against field tests. Whilst the accelerated tests picked out bad paints, he doubted whether such paints would in many cases be recommended by the manufacturer for the job.

### Atmospheric Corrosion Protection

The other two papers discussed at the morning session were "Service Trials of Painting Schemes Applied to a Steelworks Gantry,"* by Dr. J. C. Hudson, and "The Protection of Iron and Steel by various Non-Metallic Coatings,"†, by Dr. J. C. Hudson and Dr. T. A. Banfield.

The former is a description of the results of practical painting trials on a gantry in the Appleby Frodingham Iron and Steel Works, compared with those of parallel small-scale outdoor exposure tests. Both agree in showing that the efficiency of protective painting schemes applied to steel is greatly increased by removing the mill scale by pickling before applying the paint. In the small-scale tests the average life of two-coat painting schemes over pickled steel exceeded 7·0 years, as compared with 1·5 years for steel prepared by weathering and hand-cleaning. The procedure of coating the steel with linseed oil whilst still hot, after rolling, was also tried. The results proved better than those for weathered steel, but inferior to those for pickled steel, because the mill scale left beneath the paint ultimately gave rise to cracking or local failure of the paint film.

Differences between the performance of the various painting schemes tested were found to be generally of secondary importance in comparison with those associated with differences in the surface preparation of the steel before painting.

When dealing with large tonnages of steel on a practical scale, it is doubtful whether such items as the time interval between shop painting and the application of the final coats on site could be controlled. There seems to be no reason, however, why the initial surface preparation of the steelwork and the application of the priming coat of paint should not take place immediately after fabrication under the desired good conditions. This would go far towards achieving the maximum degree of efficiency of the protective painting scheme, for, in the case of many structures, the priming coat could safely be left to protect the steel until the protective scheme was completed by the application of the final coats at the site after erection.

It also seems clear that, in order to ensure efficiency from the economic point of view, two requirements need to be met, namely:

(1) The provision of plant which would follow the fabricating shop, specially designed for descaling and painting structural steel. One can envisage a well-planned assembly of machines or apparatus for pickling, grit-blasting, spray-painting, dip-painting, and even for phosphating, stoving, and metal-spraying (*see* below).

(2) The cost of installing and maintaining such a plant could be justified only if it were kept in more or less continuous production. This could be achieved by educating the user of structural steel as to the value of correct methods of surface preparation and painting. Alternatively, until such time as the demand for these methods became universal, it should be possible, by arrangement amongst individual firms engaged in the structural-steel industry, to concentrate the production of descaled structural steelwork, at one or two centrally disposed plants, which could thus be kept running continuously.

It remains to add that a further difference between small-scale tests and the realities of practical service is the fact that the protective paints on actual structures are liable to damage and often suffer such damage, as indeed was obvious in the case of the present service trials. It is clear the effect of such damage is to reduce somewhat the advantages to be gained by correct surface preparation, as compared with the estimates deduced from small-scale exposure tests, where any damage that may occur is disregarded when assessing the results.

Nevertheless the fact remains that correct surface preparation will pay rich dividends when applied to the painting of structural steelwork. It is suggested that in cases where marked damage to the protective scheme is to be expected, the provisions for protection should go a step further and comprise a combination of a metallic coating—aluminium, lead, or zinc—with paint. Such composite protective schemes are essentially a new departure and are now being studied on a fundamental basis by the joint technical panel of the Protective Coatings Sub-Committee with the paint and bituminous protective products industries. The practical application of these methods would involve the provision of plant for metal spraying and, possibly, electro-deposition and hot-dipping as well, at the fabricating works.

The paper by Hudson and Banfield is an interim report on the behaviour of a range of protective non-metallic coatings applied to structural mild steel and exposed to field corrosion tests as part of the investigations conducted by the Protective Coatings Sub-Committee of the British Iron and Steel Research Association. The atmospheric-exposure tests cover periods of up to 5 years, and the coatings tested can be grouped under (1) painting schemes, (2) sprayed coatings, and (3) other coatings. The results to date may be summarised as follows:

(1) Two-coat painting schemes applied to pickled steel were in good condition after 5 years, but when one of these schemes was applied to steel prepared by weathering and wire-brushing, failure was observed after $1\frac{1}{2}$ years. The use of a proprietary inhibitive surface wash containing phosphoric and chromic acids on the partially descaled surface resulting from the latter treatment failed to improve matters. Lanolin-base primers incorporating chromate pigments and hardened with synthetic resin have given good results when applied to pickled steel.

(2) A process in which paint containing no volatile matter is sprayed-on hot has given good results at Sheffield but the coating shows signs of breakdown after 5 years' exposure in non-industrial atmospheres.

* *J.I.S.I.*, May, 1948.
† *J.I.S.I.*, January, 1948.

No sign of corrosion of the encased steel was visible after 5 years in the case of specimens coated with cement/asbestos to a thickness of ¼ in.

(3) A tar/tallow/lime mixture applied hot protected the steel for only about 3 years in an industrial atmosphere, but this degree of protection is comparable with that to be expected from a single paint coat of approximately the same weight. A rubber/wax sheathing applied by wrapping has given good results in an industrial atmosphere, but less favourable ones in a marine atmosphere. Vitreous enamel coatings were in perfect condition, apart from minor mechanical damage, at all the exposure stations after 5 years.

The sea-water exposure tests showed that heavy coatings of sprayed bitumen, alone or mixed with rubber or zinc, gave fairly good results over a period of 2 years' continuous immersion. The addition of glass to a sprayed zinc coating had no appreciable effect. Vitreous-enamel coatings were not appreciably affected after 2 years, apart from slight damage.

The sites on which the various protective schemes were tested included Calshot, Llanwrtyd Wells, Sheffield, Apapa (Nigeria) and Congella (S. Africa) for atmospheric corrosion, and Caernarvon and Gosport for marine corrosion. An appendix to the paper gives details of the methods of applying the various coatings.

Introducing the papers, Dr. Hudson commented that experience had shown that metal coatings covered by paint, especially paint on electro-deposited lead, gave good results with almost all types of paint, which bears out the importance previously attached to surface preparation.

Discussion on these papers centred mainly on the fact that whilst the rate of corrosion on unpainted mild steel in Sheffield is 2½ times the rate in a rural area, corrosion under a coat of paint appears to be quicker in the country than in an industrial atmosphere. Dr. Mayne (Cambridge University) made this point and suggested as a contributory cause that "sunshine in Sheffield may be weak in certain portions of the spectrum". Dr. U. R. Evans (Cambridge University) observed that Dr. Mayne's suggestion fitted in with the observation of tar paints. He suggested an alternative theory that rain falling in an industrial atmosphere, being acidic, leached out ferrous salts through the paint films, while rain in rural areas would act in this way to a lesser extent, and the corrosion products would, in general, remain on the metal surface, thus causing the paint film to rise. He mentioned that at Cambridge, painted specimens immersed in sea water showed rust on top of the painted coat, but when the sea water was sprayed on, the rust occurred underneath the coat.

The question of vitreous enamelling was taken up by Mr. E. J. Heeley (Imperial Chemical Industries) who demonstrated the successful application of vitreous enamel to a steel with as much as 0·4% carbon. Dr. W. D. Jones (Schori Metallising Process, Ltd., London), confirmed this and described experiments of vitreous enamelling by a flame-spraying gun. Lack of success, however, was due to temperature variations on any but very small surfaces. Low melting point enamels did not have adequate anti-corrosive properties.

Dr. V. G. Jolly (Walpamur, Ltd., Darwen), confirmed the importance of properly cleaned surfaces. In exposure tests at Burnley, where the acid content of the rain is very high, corrosion was far more apparent after 10 years than in similar specimens in a marine atmosphere. Mill scale was also commented on by Dr. Mayne and Mr. Fancutt, who wanted to know how firmly adhering mill scale might be removed at reasonable cost. Mr. E. Bateson (Messrs. Rendel, Palmer and Tritton, Ltd.), was also interested in this point as a practical structural engineer. He maintained that weathering and wire brushing are the only practical methods of service preparation for steelwork in complicated fabricated parts. Pickling is dangerous, because of the retention of acid in corners and he suggested fabrication after cleaning as the solution if it were possible to protect pickled surfaces in the interim. He suggested oil spraying of hot metal as a possible solution.

Dr. Banfield considered that the ideal procedure was to clean the steel after holes were punched and drilled, immediately before the final assembly.

## Marine Fouling

The afternoon session, under the Chairmanship of Professor J. E. Harris, Chairman of the Marine Corrosion Sub-Committee, was taken up with two discussions. The first was on two papers presented by Dr. H. Barnes: "Studies on Anti-Fouling Compositions Parts I to III,"* by Dr. H. Barnes, and "Service Tests of Experimental Anti-Fouling Compositions,"† by Dr. H. Barnes, Mr. M. W. H. Bishop and Mr. K. A. Pyefinch.

The settlement and growth of marine organisms, of which the best known are probably barnacles, on a ship's hull can have appreciable effects on the vessel's speed. The problem of preventing such settlement is, therefore, one of great practical importance. It is known that settlement may be prevented or minimised by the application of a coat of anti-fouling paint over the normal corrosion resistant coatings. Such paints release poison by the action of sea water, and Dr. Barnes' paper on anti-fouling compositions contains the first three parts of a comprehensive study of them.

Anti-fouling compositions consist essentially of a poisonous pigment such as cuprous and/or mercuric oxide, a secondary pigment such as red oxide of iron and a varnish comprising a component such as rosin, susceptible to attack by sea water, a resistant second component such as an inert resin, together with a plasticiser and solvent. It is suggested that in a normally pigmented composition, in which the pigment content is insufficient for partial contact throughout the matrix, the release of poison by the sea water is as follows. The particles on the surface can be attacked directly, but once this material has been removed, further attack is dependent on the removal of rosin by sea-water attack, thus enabling the sea-water to get at the poison pigment particles below the surface. During the preparation of compositions containing cuprous oxide and rosin a certain amount of copper soap is formed, the amount depending on the conditions of milling, e.g., time, temperature, etc., The importance of this lies not so much in the loss of cuprous oxide but in the loss of rosin and its effect on the rosin/binder ratio and the rate of release of the poison. It is suggested that the variable results obtained with various batches of a particular composition are largely the result of inadequate control of the milling operation.

The third part of the paper deals with the rate of loss of material from a rosin/binder varnish exposed in the sea for two forty-day periods. The absence of a

* *J.I.S.I.*, December, 1947, p. 587.

† *J.I.S.I.*, November, 1947, p. 429.

sufficiently sensitive quantitative reaction for rosin prevents the use of a leaching technique for such a study. With the method adopted the results were average rates for the two forty-day periods with no indication of the variation during that period. Over the first forty days the loss is generally proportional to the percentage of rosin in the varnish when the rosin content exceeds 65%. Below this value the losses are small and at 30% rosin there is no loss. The losses are much reduced in the second forty days during which period calcium salts are deposited in the matrix. It is suggested that the loss is probably due to solution of the acidic rosin components. Experiments on the acidic material remaining in the film are described and calculations indicate that acid material is bound in the outer layers. The desirability of devising a leaching technique, as well as of the study of the role of bacteria in the solution of these films is stressed.

In the paper by Barnes, Bishop and Pyefinch, the results of service tests, made by applying patches of anti-fouling paint to ships' hulls, are recorded. In order accurately to assess the performance of an anti-fouling composition under service conditions it is essential to take into consideration the route, the ports of call, the periods in port, the total period of service and their relation to seasonal conditions. If all of these are known and are considered together with chemical data concerning original composition and poison loss, a reliable estimate of performance can usually be made. This can be done even if the test has been carried out in temperate waters if due account is taken of the seasonal nature of fouling settlement under such conditions, and when dockyard inspections can be supplemented by detailed microscopic observations, and can also be interpreted in the light of biological knowledge gained from raft experience. There are, however, circumstances, *e.g.*, docking in fresh water and very long service periods, which can vitiate any test. Superficial comparisons of anti-fouling performance and any one of its controlling factors can lead to entirely false conclusions, resulting in fictitious estimates of the compositions tested.

Dr. Barnes, in introducing the papers, said that the three parts of his study of anti-fouling compositions might be regarded as a sort of *hors d'oeuvres* before the main body of results which would shortly become available.* Professor Harris' leaching rate test method had been used successfully at Millport, with the amendment that slides were stored in the sea and not in a tank. Dr. Barnes indicated the need for a strict physico-chemical approach to the problem of copper soaps: consideration should be given to the effect of temperature during paint milling as this might throw some light on the difficulty in getting reproducible batches. Much interesting work also remained to be done on the loss of rosin, which was believed to govern the rate of loss of cuprous oxide, and on the effect of the binder on leaching rate.

Mr. L. J. Brooks (Henry Clark & Sons), regretted that the authors had not confined their attention to a strictly fundamental approach. He felt that there had been up to now a pre-occupation with marine biological and practical aspects, and a comparative neglect of the physico-chemical aspects. This consequently led one to suspect the validity of certain speculations based on evidence admittedly lacking in precision. There was a tendency on the one hand to ignore the complex influences of diffusion forces and the products of chemical reaction, and on the other hand to accept too readily the over-simplification implied by the rosin solution theory. He did not say these assumptions were wrong, but that one would be more impressed by the observations of a more exacting technique. He considered that the practical and semi-practical approach were normal activities of up-to-date Compositions' laboratories, and he could confirm the value of a strictly fundamental approach from experience with Dr. H. W. Keenan of leaching rate work developed before the official interest in anti-fouling research arose in either this country or America. He did not deprecate the importance of practical work ; on the contrary it should be on as large and as representative a scale as possible, provided it was developed from first principles and not itself made the primary instrument of investigation.

Mr. H. Wood (Storry Smithson & Co.), confirmed that temperatures are apt to run high in ball mills, though not so high in roller mills. He also raised the question of the addition of other soaps such as aluminium stearate and aluminium naphthalate.

Mr. W. A. D. Forbes (Admiralty), welcomed the physico-chemical approach to the problem of anti-fouling. It had been on his suggestion, five years ago, that the Marine Corrosion Sub-Committee had set up a panel to study leaching rates, and to standardise the method. That suggestion arose after he returned from a visit to America and realised the lack of knowledge on the subject among paint manufacturers in this country. The final test of an anti-fouling paint in the Navy was to see after, say, six months service, whether an increase in engine revolutions was necessary to maintain a given speed. Our paints at the moment did not fulfil that condition.

In his reply, Dr. Barnes, said, that he had heard from Dr. Ketchum in America that similar work was in progress there on copper rosinate, and that our published results confirmed their work. It was a fact that " we set out to make a composition which would be anti-fouling for one year, and that we have now compositions which are anti-fouling for two years ", which was a fair measure of the success achieved.

### Cementiferous Paints

The second two papers discussed at the afternoon session were : " Cementiferous Paints," by Dr. J. E. O. Mayne and Dr. R. S. Thornhill*, and " Marine Exposures of Cementiferous Painting Schemes,"† by Mr. K. A. Pyefinch, each presented by their respective authors.

The cementiferous paints arose out of attempts initiated by U. R. Evans, in August, 1940, to obtain rapidly setting aggregates of metal and cement by mixing steel filings with magnesium chlorate. The iron reduced the magnesium chlorate to magnesium chloride and magnesia roughly in the proportions needed to produce Sorel cement. Instead of magnesium chlorate, mixtures of magnesium sulphate and potassium or barium chlorate were sometimes employed, and other substances, such as ammonium chloride, were often added to accelerate the reaction, and carborundum to improve the hardness ; in some cases sufficient steel was

* Part IV of this study was published in the June issue of the *Journal of the Iron and Steel Institute*.

* *J.I.S.I.*, February, 1948, p. 219.
† *J.I.S.I.* February, 1948, p.229.

left after setting to confer magnetic properties on the mass.

When zinc dust was substituted for steel filings, the mixture could be brushed over a steel surface, forming a type of inorganic paint, and if the zinc content was sufficiently high the coating thus produced was capable of affording considerable protection to the metal when immersed in sea-water.

It was felt that such paints might prove superior to oil paints, for the following reasons : (i) Being based on an aqueous medium, they should be suitable for application to wet metallic surfaces. (ii) Any corrosion products on the surface of the metal would be incorporated into the body of the paint as part of the pigment. (iii) Paints rich in zinc dust should effectively protect partially descaled surfaces, since the breaks in the scale, which are potentially anodic points, would receive cathodic protection, and the dangerous combination of large cathode and small anode would be modified, thus preventing pitting of the metal and undermining of the scale.

The paper by Mayne and Thornhill, describes researches designed to elucidate the mechanism of the setting on and the protection of steel by cementiferous paints. These paints are based on mixtures of zinc dust and certain chloride solutions which produce a matrix of oxychloride cement by action on the zinc ; sufficient metallic zinc is left to provide cathodic protection to steel exposed at gaps or pores in the coat. If the electrical contact between steel and zinc, and that between zinc particles, is good the potential of the painted steel is similar to that of zinc sheet ; thus a study of potential movements provides an assessment of protective value. Of the chlorides tested, those of barium and of strontium produce setting at high and low humidities, magnesium and calcium chlorides are satisfactory except at very high humidities.

Cementiferous paints suffer from the disadvantage that they slowly break down in the presence of water owing to the nature of zinc oxychloride ; future work, therefore, on cementiferous paints should be directed towards the evolution of a more water-resistant cement. In their present form, however, they can be very effectively sealed by a coat of the normal type of paint, hence their most promising application is as priming coats. Exposure tests have shown that they are unsuitable primers under atmospheric conditions, but under marine conditions very promising results have been obtained. This application of cementiferous paints is discussed by Mr. Pyefinch in a separate paper.

Since cementiferous paints are composed of inorganic materials they are not inflammable ; this makes them very suitable for painting the interior of ships, where the fire risk is an important factor. They are also unaffected by petrol and oils, and thus provide a possible solution to the problem of protecting the interior of oil tankers. They give considerable protection against corrosion fatigue and during the war one of the paints was successfully used in the works of the Alkali Division of the Imperial Chemical Industries, Ltd., for this purpose.

DR. THORNHILL commented that the cementiferous paint E 390, with which much of their work had been concerned (Zinc dust 56g. ; Indian-Red 6g. ; China-clay 6g. ; $MgCl_2 . 6H_2O$ solution 20cc. : strength of solution 31%) would not dry over water, but over sulphuric acid dried in $1\frac{1}{2}$ to 2 hours. Even when covered with a thick film of water it would dry if taken out and put in the atmosphere again, though its appearance would be much inferior to one dried under normal conditions. He thought iron oxide and red lead (added to give some measure of inhibition) acted as accelerators of the setting mechanism since they encouraged the production of zinc chloride.

Potential measurements were used in enquiring into the mechanism of protection. Some of the best protective paints showed that the surface was behaving more or less as a continuous film of zinc. There was a tendency for zinc particles to come out of contact with the steel base, and for the negative potential to become less. Possibly the protection obtained was due to an inhibitor.

DR. MAYNE said that the only general application for the paints so far is as priming coats on ships bottoms. Here the tendency of the matrix to hydrolise is delayed by a sealing coat, and the tendency for the paint to dry out is prevented by immersion in sea-water. Both these disadvantages might be overcome by the development of paints based on phosphates or silicates, such as sodium silicate. Generous claims were made in America for one such paint called " Zincsulate."

The paper by MR. PYEFINCH describes the results of tests on painted steel specimens attached to a raft at Millport and subjected to total and partial immersion in sea-water for periods up to two years. In introducing the paper Mr. Pyefinch said that the tests were made on three schemes of painting.

In the first, steel plates were painted with a priming-coat of one of the cementiferous compositions, covered with another coat of the same, but containing an anti-fouling agent (Phenyl mercury acetate was the most successful). Although protective and anti-fouling properties were reasonably good, performance was less good on a weathered than a scaled surface, and considerable wear of the coating took place after some months in the sea. In the second stage the surface of the cementiferous paint was sealed with one coat of an oleo-resinous anti-fouling composition. Performance of such schemes over 12 months was extremely good, but after 12 months deterioration could be rapid, even if it were re-painted and re-immersed. In the third stage the cementiferous primer was sealed with one coat of an oleo-resinous protective paint and then a coat of anti-fouling paint. Such schemes led to a considerable improvement.

A series of exposures just concluded at Millport, showed only traces of rust after two years in the sea, assessing them as severely and rigidly as possible. If these exposures were taken out of the sea and repainted, they did not fail in the way that the single sealing coat systems did, suggesting that the cementiferous primer was still sound. Such coatings were also of value in application at the water line. After a period of 9 months to 1 year exposure at the waterline, such systems again had only traces of rust. It would seem on the basis of these raft exposures, that cementiferous compositions have a very promising future as priming coats for ship's painting. One might suggest that a ship should receive one coat of cementiferous paint and one coat of oleo-resinous protective before launching, and then another coat of oleo-resinous protective and the anti-fouling coat on dry-docking for fitting-out.

DR. U. R EVANS (Cambridge University) thought cementiferous paints had little application "for general terrestrial use", though it might be possible to use them for purely decorative purposes on wood and plaster. As primers for ships' paints, care must be taken that the sealing coat should not contain lead compounds, nor should the cementiferous coating be applied over old organic paints. Their use tends, therefore, to be limited to new ships or to ships which can be scraped. Tests were now in progress on ships, and more were planned. The elimination of paints based on drying oils, in ships, in favour of paints that do not burn would be a great advance, and work was in progress at Portsmouth on the subject. The addition of industrial alcohol made possible a cementiferous paint which would keep ready mixed for reasonable periods. MR. H. WOOD (Storry Smithson & Co.) asked whether ships plates immediately after pickling might not have a coating of cementiferous paint to preserve them from rust. DR. HUDSON (B.I.S.R.A.) said that "we do not inevitably get the best results from a protective system for immersion in sea-water by applying a paint immediately to freshly pickled steel. As a matter of fact, if we were to pickle a plate and leave it for a reasonable time, say, two or three weeks, on the whole it would be an advantage," This was, of course, in contrast to steel for what Dr. Evans had called "terrestrial use." MR. W. A. D. FORBES (Admiralty) pointed out, however, that this procedure might be very valuable if applied to plates for above-water construction. MR. C. GORDON SMITH (Alfred Holt & Co.), asked what sort of cleaning would be necessary before making good the wear and tear that ships suffer, particularly in the Far East. THE CHAIRMAN, queried the possibility of using cementiferous paints to combat corrosion on the inside of tankers.

In replying, DR. THORNHILL, said that he thought Dr. Evans exaggerated in saying that these paints were no good for "terrestrial use." They got a life on the Cambridge roof of about 9 months, and he thought they would have some reasonable application. A pickled surface could certainly be covered with a cementiferous paint. On the question of use in tankers, the paints had been found to be resistant to petrol and oil, and to have a reasonable degree of protection against sea-water or ballast. There seemed to be a field here for their application. DR. MAYNE confirmed this, but commented that the inside of the tanker would have to be free from rust if a satisfactory life were to be obtained for the coating.

MR. PYEFINCH, claimed that the three-coat system was no more elaborate than the present painting scheme for a new ship. On the question of renewing a cementiferous coat it appeared from their raft experience that if the cementiferous primer had been effectively sealed it was very difficult indeed to remove it from the steel surface: in fact, in the laboratory it had been found necessary to pickle the steel plate to remove it. Renewal of the cementiferous coat should not be necessary, and the oleo-resinous coat could be applied over it.

## Nickel Price Increased

### Large Low Grade Ore Body to be Opened

THE International Nickel Company of Canada, Ltd., and its associated companies, The International Nickel Company, Inc., in the U.S.A., and The Mond Nickel Company, Ltd., in the U.K., have increased their prices for nickel. In Europe the Mond Nickel Company is raising its prices to £224 per ton, delivered works, in the United Kingdom, and to £227 per ton, c.i.f. continental port, on the Continent. These prices correspond to those announced for Canada, the U.S.A., and the rest of the world.

The increase in Europe is the first made by the companies since 1939. It has been necessitated by the considerable and continued rise in costs, particularly in Canada. In commenting on the price increases, Mr. Robert C. Stanley, Chairman and President of The International Nickel Company of Canada, Ltd., stated that the increased metal requirement of the world since the pre-war has placed a heavy drain on the ore reserves of the base metal producers, who have been forced to mine lower grade ore bodies with consequent increases of costs and upward pressure on prices. The Company is now mining underground ores of considerably lower grade than in the pre-war and it has decided, in order to preserve a stable supply of nickel, to start a long-range mining programme which will open up a large underground ore body at Sudbury, of a grade much below its average.

In common with other industries, The International Nickel Company's costs of supplies and services and of labour rates have risen approximately 100% from pre-war levels. Wage increases in Canada this June, together with previous increases granted in 1947 and 1948, alone have added approximately ten million dollars per annum to plant costs. The result is that, in spite of many plant and process changes, introduced to effect economies, costs have greatly increased and must be compensated for by a rise in the price of nickel. The Company and its subsidiaries have deferred advancing their prices until it became entirely apparent that the increased cost factors could not be regarded as merely temporary phases of the post-war. In keeping with the long-range policy of developing new uses and broadening the demand for nickel the price is being kept as low as possible.

The increases will bring the price of nickel to a level only 25% above the prices generally prevailing in the pre-war years. By comparison the quoted prices of other base metals, copper, tin, zinc and lead, have increased from nearly 100% to over 200%.

## The Nickel Bulletin

THE monthly article in the June issue of "The Nickel Bulletin" touches on the full range of non-ferrous castings, in which nickel plays an important part. "The Bulletin" also includes useful data on the approximate relationships between the various hardness numerals obtained from nickel and high nickel alloys, in addition to numerous abstracts under the headings of electrodeposition, nickel-iron alloys, cast irons, constructional steels and heat- and corrosion-resisting alloys.

"The Nickel Bulletin" is obtainable free of charge from the Mond Nickel Company, Limited, Grosvenor House, Park Lane, London, W.1.

# The Atomic Energy Research Establishment

## Progress in Research and Development

*To what extent atomic energy will be applied in the future, none can say, but there can be no doubt that its potential uses have tremendous possibilities for good as well as for evil. Some indication of the progress in the research and development of atomic energy at Harwell is given as a result of a recent visit to the Research Establishment and some of the units installed or in course of erection are described.*

PRIOR to 1939, it is doubtful if many people had heard of the peaceful little village of Harwell, on the edge of the Berkshire Downs, four miles from the market town of Abingdon. During the war it was decided to erect a Royal Air Force Station there and to make an air field. This was done and the station comprised four large hangars, barrack blocks, workshops and upwards of eighty permanent houses.

In 1945 the world was introduced to the subject of Atomic Energy and in November of that year the Ministry of Supply decided to found an Atomic Energy Research Establishment. In order to provide a nucleus of accommodation and a prepared site, the permanent airfield of Harwell was allocated to the Establishment and the little village was at once "on the map". Harwell was chosen because of its convenient geographical location, combining reasonable access to London with nearness to the University City of Oxford, for it was considered important that staff should have opportunities for discussion with University colleagues.

Here it should be pointed out that the comparison so often made, that working conditions for scientists at the Universities are much more advantageous than at Government Research Establishments, is quite wrong, at least in connection with Harwell. The general atmosphere at Harwell reminds one of a University except that the laboratories and workshops are equipped in a manner which would doubtless be of envy to most Universities, and the Staff there are in constant touch with the University research departments and particularly with Oxford. Although a certain amount of secrecy is, of course, essential, the Staff are, whenever possible, free to publish the results of non-secret work and to discuss this freely with other scientific bodies.

The best possible use has been made of the existing R.A.F. buildings. The hangars house the large machines and piles, also a central workshop, while most of the barracks have been converted into laboratories for physics, chemistry and biology. The old navigational training department now houses a high-voltage generator, together with diffusion columns for the separation of isotopes and a chemical engineering workshop. The airfield workshop is used for machining to high precision, the graphite used in the piles; the water tower is used for the long columns for the production of the heavy carbon isotope for biological research and so on. But in addition to all this, much new building has been erected, including laboratories. Then there is the matter of living accommodation for the Staff. A fair amount of this was available from the existing building of the airfield, but it has been supplemented by two colonies of about one hundred pre-fabricated houses.

It must, however, be pointed out that the Research Establishment is by no means finished. A large new laboratory is being built for work on the chemistry of radio-active materials and accommodation is to be provided for metallurgical, health and medical work, whilst more permanent houses are being constructed in the nearby towns of Abingdon and Wantage.

### Object of this Establishment

Primarily, this Establishment was founded to carry out fundamental research and development in atomic energy. It is, however, also responsible for providing scientific and technical information to the Controller of Production of Atomic Energy, Lord Portal of Hungerford, and his organisation at Risley, which is at present engaged in the construction of higher-powered piles in Cumberland for the production of plutonium. It will be the source of radio-active isotopes for this country and will make it possible to extend the supply of isotopes to members of the British Commonwealth and other overseas countries. Its work also includes fundamental research in nuclear physics.

In January, 1946, Professor Sir John D. Cockcroft was appointed Director of Harwell. Sir John Cockcroft became famous when associated with the late Lord Rutherford at the Cavendish Laboratory, Cambridge, and it was he, together with E. T. S. Walton, who achieved world renown as the first to disintegrate the nucleus by artificial means. This was followed by his election as a Fellow of the Royal Society and the award of the Hughes Medal. During the last world war his activities included a leading part in the development of radar and precision gunnery for A.A. Defence. In 1940 he visited the U.S.A., and there was largely responsible for that mobilisation and close co-operation of the British and American scientific resources, which profoundly influenced the subsequent course of the war. Whilst not at that time directly concerned with the atomic bomb project, he became closely associated with the development of atomic energy in 1941 and was responsible for the construction of a large-scale establishment at Chalk River, Ontario. He was awarded a C.B.E., in the 1944 Honours List, received the honorary Degree of Doctor of Laws of the University of Toronto in 1945 and a Knighthood in the New Year's Honours List of 1948.

### Address by Sir John Cockcroft

Unfortunately Sir John Cockcroft could not be present on the day of the visit but an address from him was read by a member of the Harwell Staff. In it, Sir John welcomed the members of the technical press and

**A general view of the Atomic Energy Research Establishment, showing the new engineering building to the right of the centre, the Ridgeway House Staff Club to the left of cricket pitch, with ex-R.A.F. brick houses, now used for the staff, behind. Left of the foreground are the laboratory buildings.**

said that every effort would be made to show something of the progress which had been made in two years towards building up atomic energy research in this country. He was fortunate in having a nucleus of first-quality staff, some of whom had acquired experience in Los Alamos and Berkeley in the United States whilst others had helped to build the atomic energy plant in Chalk River, Canada. They had added to this nucleus by recruitment of junior staff and, today, they had divisions of theoretical physics, nuclear physics, general physics, chemical engineering, metallurgy and health, all of the size of large University research schools. Their first duty was to equip themselves for atomic energy research, and, in particular, for research in the development of nuclear reactors. The simplest class of reactors were those built from graphite and natural uranium. This was not at all easy, but in fifteen months they built the simplest possible pile, developing about 100 kW of nuclear energy. This was the pile known as Gleep (graphite low energy experimental pile). This pile had been used for 11 months for experimental and research purposes, also for the purpose of producing radio-active isotopes.

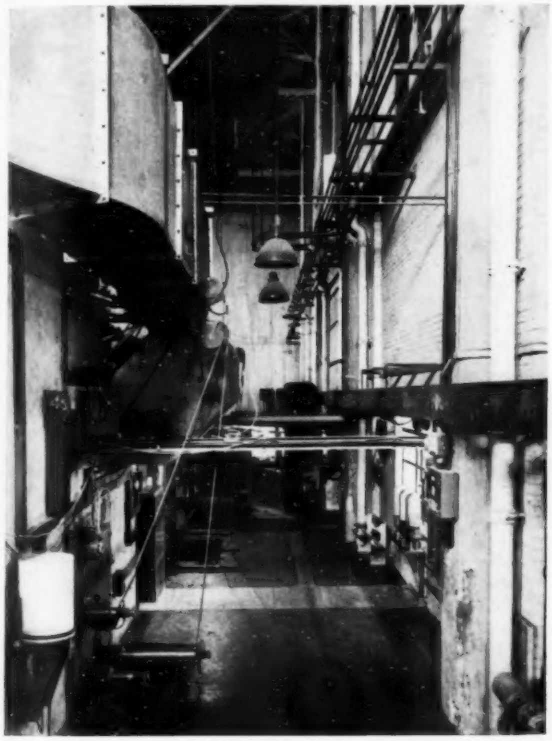
In order to ascertain how materials would stand up to the intense bombardment they received inside piles, a more powerful one had now been built, developing 6,000 kW of energy and capable of bombarding 60 times as strongly as Gleep. This had received the name of Bepo (British experimental pile). The last bars of uranium were loaded into it on July 3rd, while instruments recorded the number of neutrons being produced and the amount of heat being generated. At 3-0 p.m., the instruments recorded 3/10ths of a watt so a little more metal was loaded and the power began to grow, showing that the divergent point had been reached. The power rose more and more rapidly until at 35 watts safety rods were crashed into the pile by compressed air and the pile was shut down in accordance with arrangement. They now had to go through a period of testing at low power before commencing the programme of new work.

Sir John then made reference to several of the other units at Harwell, more details of which will be given later. Finally, he said : research work in atomic energy included much that was fundamental scientific work and was no secret. Other parts of their work were more technological and disclosure of information might be used by other countries to assist in the production of atomic weapons. There were, of course, many border-line subjects and these would be reviewed periodically to determine which parts of the field could be released for publication. Everything to be shown was non-secret. A particularly interesting case was the Gleep. The exterior of the pile could be shown and its experimental facilities could be described. On the other hand, however, the details of its internal construction, the technology of graphite, the uranium metal making and the detailed lattice structure of the pile were technological and must remain secret.

## Some of the Units

The most important and by far the most interesting units were the two piles, Gleep and Bepo, though so far as the latter was concerned, the view obtained was, to use a misplaced technical term, under a certain amount of "remote control". Gleep is a slow neutron reactor, consisting of several hundred tons of graphite acting as moderator. That is to say, its function is to slow down neutrons to thermal speeds this being an essential of all reactors. The fissile material is, of course, natural uranium metal of which the pile contains a few tons. The power level at which it operates is controlled by cadmium rods hanging vertically in the pile, but a second set of rods is provided in order to shut down the pile if this is necessary. The power at which it is operating is measured by chambers sunk into the pile. These contain a gas, boron triflouride. When neutrons impinge on these gas chambers, a small electric potential

is set up which is recorded in the instruments in the control room. In addition, automatic recordings, from connections within the pile, are provided of the temperature and other physical constants inside the pile. The radiation from the pile is, of course, extremely dangerous, due to the gamma radiation in particular, and the greatest precautions have to be taken to prevent this escaping. The pile is therefore surrounded by a concrete shield several feet in thickness. Nevertheless radiation " monitors " are also installed in the building and these will give indication of any radiation which has escaped and which is present. Control is remote as is always the case with apparatus connected with any operation in the course of which there is emission of gamma radiation.

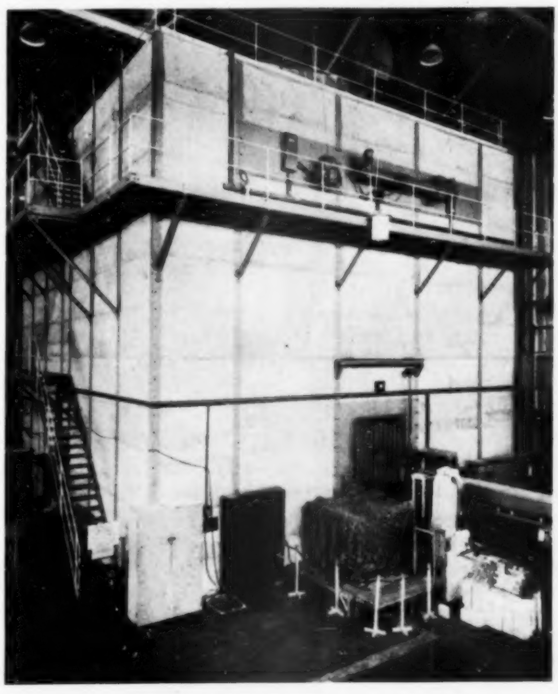


**The " control " face of Gleep is on the left. In the bottom corner are the chambers containing boron triflouride gas used to measure the intensity of neutrons in the pile, and hence to control the power level at which the pile is operated. On the right are the health monitoring instruments and behind them is the control room.**

The other and larger reactor, Bepo by name, is similar to Gleep in that it uses graphite as moderator and is air-cooled. The main body of the pile consists of several hundred tons of graphite blocks and into these a large number of cylindrical rods of uranium are arranged in the form of a lattice. Each uranium rod is enclosed in an aluminium " can " and they lie in channels cut into the graphite blocks. Several large electrically-driven exhausters are used to draw the cooling air through the pile in order to remove the heat which is produced by the fission and chain reaction of the uranium rods. As is usual the whole pile is surrounded by several feet of concrete and the cooling air is discharged up an enormous stack, some 200 feet high. The protective shield of concrete is, however, pierced by holes. There are upwards of forty of these and they are the means by which access is gained to strong fluxes of neutrons in the interior of the pile. A much more intense production of neutrons is obtained inside the reactor than by any other means and they are of the greatest benefit for research into nuclear science. Another very important function of these neutrons is the production of radio-isotopes. Inactive elements, if submitted to the action of neutron bombardment will be transformed into radio-active isotopes and these holes in the protective shield can be used for the insertion of such elements.

Similarly to Gleep, the operation of the reactor is controlled by neutron-absorbing rods. Here they can be pushed in or out of the pile at will, and are operated from the control room as desired. Two sets are used, one for the normal working of the pile in order to keep it at the required power level while the second set is only used in case it becomes necessary to shut down the pile for some emergency. Possibly, for example, the pile may become over-heated, or it may be found that for some reason, there is an undesirable degree of radio-activity outside the pile. Apart from this, they will operate automatically if there is a failure of the air-flow and an electric power failure producing the same cause.

The necessity for the most exact details cannot be stressed too much in a piece of apparatus of this character. The Royal Dockyard at Devonport fabricated and erected the main steel framework of the pile to a degree of accuracy unique in a structure of this type. Special workshops at Harwell machined the pure graphite into



**A general view of Gleep showing, in the face on the right, the holes through which samples are put into the pile for the production of radio-isotopes. In the same face a square screen of lead blocks covers the thermal column. The latter is a column of graphite used to produce slow, or " thermal," neutrons for experimental work.**

**A sample being taken out of the Gleep after irradiation. The samples are placed in the lead pots (centre) for transport. Cans with new samples awaiting irradiation are in the stand in the foreground. An instrument for measuring the amount of radiation is on the left.**

the blocks and the uranium was cast at the Rocksavage Factory of Imperial Chemical Industries and at the Springfields Factory of the Ministry of Supply.

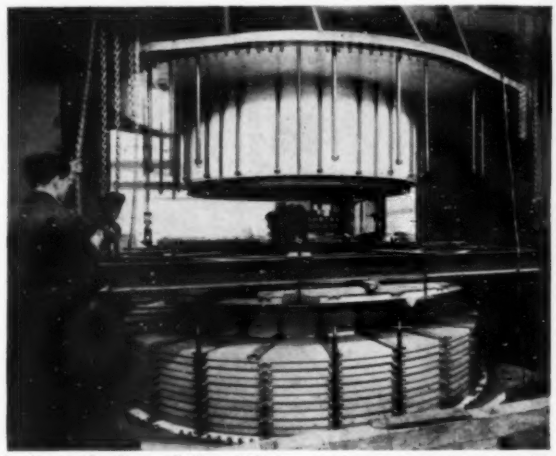
### Radio-Isotopes

An accompanying illustration shows the withdrawal of radio-isotopes from Gleep. It will be seen how, in this instance, the substance being used has been placed in a small aluminium can which in turn has been inserted into a graphite block. This had been pushed into the middle of the pile, remaining there until there had been sufficient time for it to have been bombarded sufficiently by the host of neutrons inside the reactor. Immediately it is withdrawn from the graphite block, the radio-isotope is ready for use in the field for which it is required. There are innumerable uses for these radio-isotopes at the present time both practically and for research purposes and, as time goes on, there will be greater demand for them. At the moment, perhaps the most important use is as a substitute for radium.

By the means outlined, it is possible to produce them in considerable quantities and consequently much more radio-active substance is obtained than would be possible if radium were the only material available. In addition to their uses in medicine, however, there is also a big field for them in chemistry, physics, biology, agriculture and last but by no means least, in the science of metallurgy.

### The Cyclotron Magnet

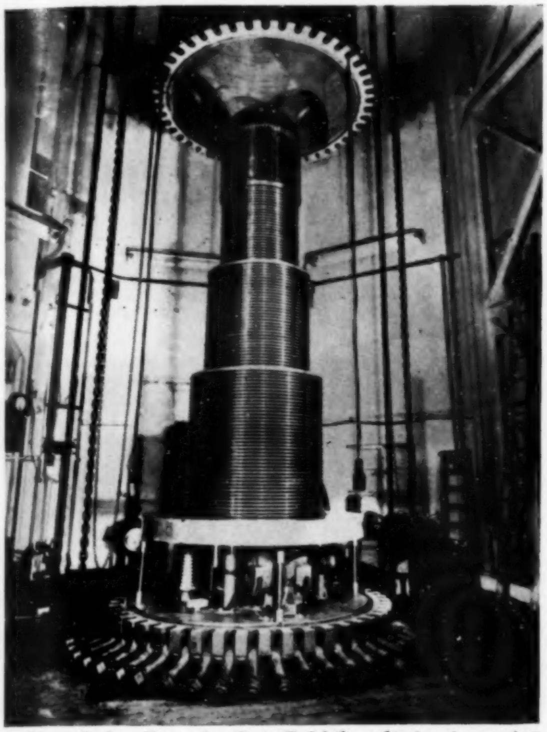
It is unfortunate that this unit is only in its early stages of assembly, since to see one of these machines in action is to experience the feeling of being in the vicinity of enormous energy, which, of course, is the case. An accompanying illustration shows the magnet in position. The poles are 110 inches in diameter and the magnet itself complete weighs 700 tons. Between the magnet poles will be placed the "dees". These are two flat, hollow semi-circular boxes inside which positively charged particles will be whirled round in a spiral path and at rapidly increased speed as a result of the application of an alternating potential applied to the dees by a power of 1,000 kilowatts. The object of this machine is to impart to the positive particles energies of about 200 Mev (million electron volts). This does not mean that the particles will possess a charge of this amount but they will have acquired an energy equal to that given to them had they fallen through such a potential difference. It is of course not possible to produce or give such a charge directly but it can be done merely by using 1,000 kilowatts in the cyclotron. The particles to be used will be protons or deuterons, the proton being the fundamental positively charged particle and the nucleus of the hydrogen atom while the deuteron is the nucleus of "heavy" hydrogen consisting of one proton and one neutron. Their use will be to bombard and disintegrate other nuclei making possible experiments in nuclear physics and with the various isotopes of nearly all the elements in the periodic table. The present machine will probably be completed about the end of this year when probably more will be learned of its work and capabilities.



**A general view of the 110-in. cyclotron magnet during erection. The magnet contains 700 tons of steel. Some of the copper windings have been installed on the lower pole. There will be six pairs on each pole when the magnet is completed, containing a total of about 70 tons of copper. In the illustration the gap between the pole faces is 40 in., but when completed this gap will be reduced to 12 in. It is in this gap that protons or deuterons are accelerated.**

### The Graaff Generator

Another machine used for much the same purpose as the cyclotron, but of lower energy is the Van de Graaff generator. This is a modification of the original type of generator invented by Van de Graaff in America and though the use of the Harwell machine is apparently for accelerating hydrogen nuclei for the study of the properties of atomic nuclei, similar machines can be used for dealing with negatively charged particles. The principle of the machine is comparatively simple. A small, rounded insulated terminal is enclosed in a pressure-boiler which is filled with gas under a pressure of about 200 lb./sq. in. to prevent any sparking to earth. A belt conveyor transfers electric charge from earth to the terminal. This belt travels at a speed of one mile per minute and is made of rubberised material. It is loaded and unloaded with electricity by a row of points at either end which cause a discharge to and from its surface. An auxiliary supply provides a voltage of 50,000 needed to make the discharge occur. By this means there is a collection of potential at the top of the machine which amounts to as much as five million volts.



**A view of the Van de Graaff high-voltage generator. When in use this machine is enclosed by the boiler top centre, which is filled with gas under pressure.**

This voltage speeds up the hydrogen nuclei in a vacuum tube, much like a large cathode-ray tube, in the centre of the machine. They discharge through this tube into a pit below where they are used for the purpose already stated.

### Auxiliary Departments

Among the most important of the auxiliary departments visited was the radio-chemical laboratory, specially designed for the safe handling of all types of radioactive materials in laboratory quantities, also building 149 which is a converted R.A.F. barrack block specially adapted for similar work when larger amounts of radio-activity have to be dealt with. This will be transferred to the new "hot" laboratory, to which reference has already been made, when this latter is completed. Included, also were the workshops which comprise one large workshop, with 45,000 sq. ft. of floor space, together with a number of smaller shops. These are equipped with the very latest appliances and machines and are concerned with instrument manufacture, medium and heavy machining, light fitting, sheet metal work, heavy fitting and erection. Auxiliary services include tool making, wood-working, pattern making, inspection department, etc.

It will, therefore, be realised that the Harwell Establishment is almost entirely self-contained and is able not only to maintain itself but also to manufacture materials required in the course of its work as an atomic energy research establishment.

### Health Precautions

One of the important functions of one group of workers at Harwell is the health of the staff as a whole. The possibility of dangerous radiation escaping from the piles and from other sources make it necessary that every precaution be taken to prevent any ill effects. A Health Physics Group has been formed, which devotes the whole of its time to general monitoring of the personnel. This includes the issue of radiation sensitive pocket films to all workers liable to be subject to radiation. There is also a hand and clothing contamination service for the scientific and industrial staff. In addition, regular surveys are carried out with portable monitors. to check up radiation levels in active laboratories. Air samples are taken for analysis and measurement. The service is also responsible for the demarcation of areas in which radiation is found to be present, to which unauthorised personnel is at once forbidden. Monitoring is also undertaken of the grounds and atmosphere by installed monitors as well as by the analysis of collected samples of dust and air. By these means it is fully ensured that there is the minimum possible risk of any contamination by staff or by others whose business takes them within the boundaries of the Establishment.

But the possible effects may go further afield than this, When the Establishment is in full swing, as much as one million gallons of water per day will be used for the cooling of plant, for domestic requirements, and for research processes. This water is taken from the river Thames and its effluent is returned there. In order that there shall be no possible danger the most elaborate precautions are being taken to deal with this effluent before it is again returned to the Thames. Any highly activated water is segregated and is not returned to the river at all, but the remainder is delivered into storage tanks where it is tested by survey officers for compliance with the agreed tolerance, treated with chemicals for impurities and then mixed with the domestic waste water before entering the discharge pipe. All the safeguards have received the approval of the Ministry of Health, but, in addition, the Thames Conservancy Board will have samples taken at regular intervals for test purposes. The Ministry of Supply is providing facilities for testing such samples at a small riverside laboratory, when Ministry scientists will take sample tests and assist the Thames Conservancy in theirs.

### The Personnel

It was obvious that in all departments there was the greatest possible keenness and interest in the work being undertaken. The impression was obtained that were it in the direct control of this staff to hasten the knowledge and practice of atomic energy, nuclear energy, and their allied branches of physical science, it would not be long before the results would be available for the benefit of mankind in general. Activity abounded everywhere, and from information received it is apparent that this activity does not end with the working day. The Establishment is almost a self-contained town in miniature, possesses a recreational association, playing fields, squash and badminton courts, horticultural society, women's club and dramatic club. But this is not all. A group of nissen huts have been converted into a Centre which boasts a licensed bar and snack service. There are also two orchestras and a choral society while in the near future it is hoped to have a swimming pool, a theatre and a gliding club. A weekly news-sheet and a quarterly magazine are published. It will, therefore, be realised that the personnel of this Establishment are fully alive and one left feeling that at Harwell at least a great deal would soon be done for the country in atomic energy research.

# High Quality Pressure Die Castings

By James L. Erickson

*One of the difficulties in the production of heat-treated aluminium-alloy die castings is the blistering which occurs on heating to solution-treatment temperatures, as a result of the die cavity air being trapped in the casting. Whilst this article treats the matter from the standpoint of aluminium alloys, the various points raised are worthy of consideration in connection with the production of die castings in other alloys, with better and more consistent mechanical properties as a result of the reduction of porosity.*

WHEN aluminium-base alloys in the pressure die-cast state are heated to just below their solidus temperature, they tend to blister and distort dimensionally, and for this reason the solution heat-treatment of aluminium-base alloy pressure die castings is to-day an accepted commercial impossibility. The fact that pressure die-cast aluminium-base alloys blister and distort prevents the die caster from offering his customer the advantages which he might otherwise derive from the employment of castable heat-treatable aluminium-base alloys. Were it not for this undesirable consequence of solution heat-treatment, aluminium-base alloy pressure die castings might be produced, which possessed exceptionally superior mechanical properties compared with the mechanical properties of ordinary unheat-treated pressure die castings.

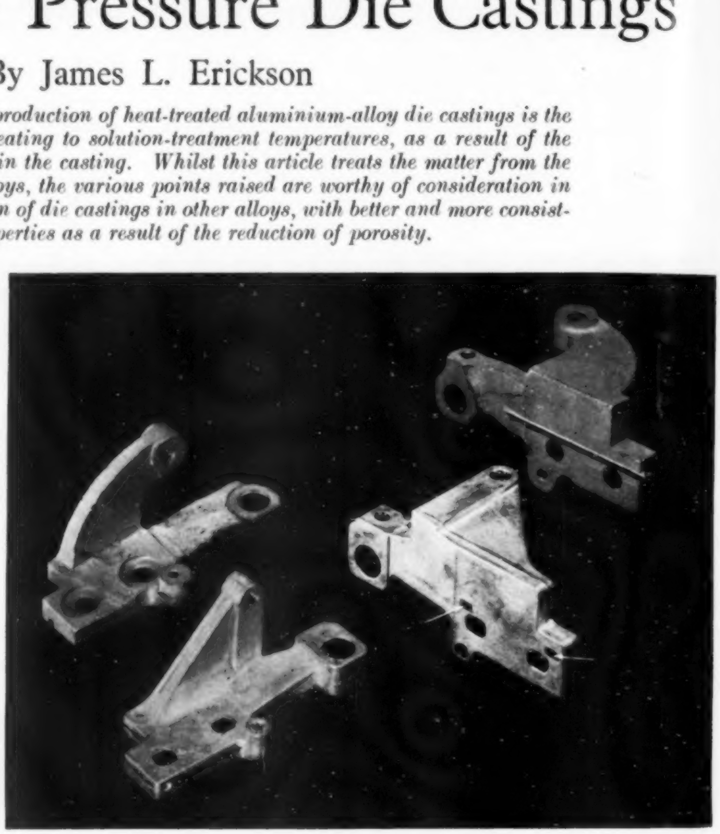


**Fig. 1.—Two views of a grey iron casting and of an aluminium-base alloy casting, pressure moulded. The latter casting was delivered in quantities at a lower cost per casting than the original grey iron castings, and it is noteworthy that considerably less machining time was involved.**

The writer began as early as 1939 to investigate the cause and prevention of blistering and distortion in die castings on heating to elevated temperatures. Some of the conclusions of this protracted investigation are herewith presented to readers :—

Blistering, other than that due to the presence of carbides, is caused by the expansion of air trapped within the pressure die casting as the casting is heated. The trapped air is free to expand when the casting is hot because the aluminium-base alloy of which it is made is soft at elevated temperatures (above 400° C.) and cannot resist such expansion. The reasons for this conclusion are : (1) Those pressure die castings which are host to the greatest internal porosity, as measured by macroscopic radiographic inspection, evidence the maximum blistering and distortion upon heating to elevated temperatures. (2) Pressure die castings prepared from hydrogen-free aluminium-base alloys under strict foundry control, but which do contain trapped air porosity, as detected by macroscopic radiographic inspection, blister and distort on heating. (3) Pressure die castings made from aluminium-base alloys which have been subjected to *intimate* contact with live steam, but which do not manifest macroscopic internal porosity upon radiographic inspection, blister and distort only negligibly. (4) Any hydrogen retained in solid solution in the pressure die-cast aluminium-base alloys would tend to diffuse out of the alloy, due to the extreme mobility of the hydrogen ion in the aluminium-crystal lattice. Such diffusion would be increased by elevated temperatures and it is unlikely that the freed hydrogen would collect in separate internal locales to expand therein and form blisters. On the other hand both oxygen and nitrogen atoms do not tend to dissociate and become adsorbed into the solid aluminium interface, and hence cannot diffuse through the crystal lattice of solid aluminium. These gases would thus have no manner of escape once trapped, and would merely tend to expand upon heating. (5) Spiral-shaped pressure die castings made from a hydrogen contaminated aluminium alloy only exhibit blistering and distortion at the extreme end of the spiral, where the molten alloy comes into direct contact with the air confined in the spiral die cavity.

It is concluded, therefore, that the trapped air porosity within the ordinary pressure die casting is the source of the disastrous blistering and distortion which make the commercial heat-treatment of aluminium-alloy pressure die castings impracticable.*

* Pressure die-cast magnesium and zinc-base alloys have no less a tendency to blister or distort than the aluminium-base alloys.

It stands to reason, therefore, that if pressure die castings could be produced which were free of internal trapped air porosity (as opposed to internal shrinkage porosity) they would be heat-treatable, and consequently if they were pressure die cast from heat-treatable alloys and subsequently heat-treated, they might well manifest some heretofore unattainable mechanical properties.

The origin of trapped air is obvious. It is merely the air which is in the die cavity, the runner cavity, and the injection well at the time the " shot " is initiated. In some instances the volume of this air may be as much as 10–15 cu. in. in the case of the cold-chamber type pressure die-casting machine, and even greater in the case of the gooseneck type pressure die-casting machine, where there is considerably more air present in the gooseneck.

As the molten metal is forced into the die cavity the air therein is compressed according to Boyle's law. The nitrogen in the air is insoluble in the molten aluminium-base alloy even under the pressure of the incoming molten metal, and consequently it does not dissolve in the molten alloy. The oxygen in the air does react partly with the incoming molten metal, and this reaction is in proportion to the degree of turbulence of the incoming molten metal stream. Oxygen, also, is not soluble to an appreciable extent in molten aluminium alloys, even under the injection pressure, and it, therefore, does not dissolve in the incoming molten metal.

Often the air that is confined in the die contains a certain percentage of moisture. This reacts with the incoming molten metal to form aluminium oxide and hydrogen gas, which is partly dissolved in the molten aluminium alloy, while the remainder of the hydrogen is left as a gas in the die cavity.†

Whenever die lubricants are employed on the die-cavity face, or the ejector pin faces, they may be vaporised and broken down (depending upon their composition) by contact with the molten aluminium alloy to form additional insoluble gaseous products, which add to the total amount of gas present in the die cavity.

It is this gas which, when trapped inside the solidifying pressure die casting, gives rise to blisters and distortion when the casting is heated to temperatures close to the solidus temperature.

### Avoiding Action

Many attempts have been made and are still being made to solve the problem of the trapped air, water vapour, and/or vaporised hydrocarbons. Of all the sundry attempts actually made, none to date has truly solved the problem. Some methods, such as that of evacuating the dies before or during the period of die-fill, have failed to attain commercial feasibility because of their high cost. Others, such as the extensive use of vents, have been found to be limited in the extent to which they can remove the confined air. Still other methods, such as the employment of overflow pockets, have their disadvantages and limitations. There is no completely foolproof method for producing pressure die castings free of trapped air porosity.

*Evacuating the Air.*—The employment of a vacuum pump to evacuate the air contained in the die cavity is expensive, and unless, as has been tried, the entire machine is operated in a vacuum, it is almost impossible to get the air out of the die cavity without its leaking back in again, even if the interval between evacuation and injection is short. Besides, to evacuate the air from a large die cavity in a short interval, it is necessary to have a large pump and a comparatively large opening leading from the pump, or storage tank, to the die cavity; this creates a problem, for this passage must be closed at just the moment molten metal is about to enter it, else the molten metal will escape into the evacuating line. At any rate, evacuating the die cavity is not only expensive, it is cumbersome. Perhaps some clever engineer will make this method work in the future. The writer thinks it warrants further investigation as it appears the only truly sound avenue of approach to the pressure die caster's problem.

*Venting the Die.*—The most universal method employed to-day for solving the trapped-air problem is that of venting the die cavity so as to permit the escape of the confined air at the same time as the molten metal enters the die cavity and fills it. The theory is that the incoming molten metal will force the air out of the die cavity and thereby eliminate the possibility of its entrapment. Vents are merely passages machined on the face of the die blocks in the form of recesses about 0·005–0·008 in. deep and anywhere from ¼–1 in. wide. Vents are also occasionally machined on cores and ejector pins to permit the escape of air past the core pins or ejector pins. The vent dimensions are such that they permit the passage of air but not of molten metal. Since venting can be done only along the plane of die parting and/or along cores and ejector pins, it has limitations. The main limitation is that once the vents are sealed by solidifying metal further escape of the trapped air is prevented. This means that unless the die cavity fills in such a fashion as not to seal off the vents until the die cavity is filled, some air will remain trapped within the molten metal. In other words, the geometry of the die cavity, the direction of the incoming molten metal stream, and the location of the vents all play a rôle in determining the success of vents in eliminating the trapped air. Unfortunately it seldom happens that all three of these factors are favourable to the escape of the air, with the result that vents generally do not permit the escape of all the confined air. Castings, for example, are generally gated in the plane of die parting and the incoming molten metal stream enters at high velocity in the form of a jet and seals off the vents before they have a chance to permit the escape of all the confined air.

The geometry of the gate determines, in part, the shape of the jet of incoming molten metal; the pressure and the density of the molten metal also play a rôle in determining the shape of the incoming molten metal jet. When the gate is small the jet has a large momentum and upon entering the die travels quickly to the far recesses of the die cavity, flowing along the die-cavity walls where it seals off the vents before all the air has escaped.

*Overflows.*—Another contemporary method of getting rid of air confined in the die cavity is to use overflows. These are actually extra cavities, machined into the die face at judicious points around the main die cavity, in the form of pockets into which the molten metal can flow from the die cavity. Passages are machined from the main die cavity to the overflow. These are large enough to permit the passage of metal (0·015–0·030 in.) but small enough to enable them to be sheared off by a trim die from the main portion of the casting. The theory of their use is sound, but their use is limited, as in the case of vents, because their inlets originate in the

† It must be remembered that the total die-filling time is seldom longer than a second.

plane of parting of the die. Overflows are used to prevent the molten metal ray from entrapping air within the main die cavity, by diverting the path of the molten metal ray so that it washes the confined air out of the main die into the overflow cavity. Overflows have other uses also, but these need not concern us here. Frequently the geometry of the pressure die casting is such that the use of overflows is of little value.

*Turbulence.*—Even though a die contains extensive venting and abundant, well-located overflows, its die cavity may be of such a contour that the incoming molten metal ray is immediately broken and a state of violent turbulence set up within the die cavity during the die-filling interval. This turbulence acts to entrap air before it can escape out of the vents or be washed into the overflows.

*Method of Filling the Die.*—From what has thus far been said, it should be obvious that the manner in which the molten metal ray enters the die cavity and fills it with molten metal has great bearing on whether or not the confined air within the die cavity will be forced out through the vents and/or washed into the overflows, or whether it will be entrapped within the die cavity.

The manner in which the die cavity fills is dependent upon many factors—viz.: (1) The density of the molten metal; (2) the geometry of the runner leading up to the gate; (3) the cross-sectional design of the gate; (4) the applied pressure on the molten metal as it passes through the gate; (5) the temperature of the molten metal; (6) the chemical composition of the metal; (7) the geometry of the die cavity, etc.

Briefly: (1) The smaller the gate; (2) the higher the applied pressure; (3) the higher the metal temperature; and (4) the heavier the alloy being pressure die cast, the greater will be the momentum of the incoming molten metal ray and subsequently the greater the turbulence within the die cavity. Also, the greater the momentum of the incoming molten metal ray, the farther the ray will travel within the die cavity before stopping. Die-fill takes place in a violent, turbulent fashion—a condition conducive to the entrapment of air—when the jet is small in cross-section and when it travels at high speed.

### Gating Experimental Castings

The author conducted a series of experiments calculated to learn whether or not: (1) Entrapped air within the solidified pressure die-cast alloy had any effect on the room temperature-properties of the alloy; (2) entrapped air actually was the cause of blistering of pressure die-cast alloys when they are heated to elevated temperatures (above 400° C.); (3) the method of—(*a*) gating, (*b*) venting, and (*c*) overflowing had any bearing on the amount of air entrapped within a die casting. The results of these particular experiments demonstrated that: (1) When the molten pressure die-casting alloy was forced into a die cavity through a small gate under high pressure, the resulting casting—(*a*) contained trapped air, (*b*) blistered severely on being heated, (*c*) exhibited inferior room-temperature mechanical properties, and (*d*) was host to abundant macroscopic internal porosity; (2) the use of vents at certain points tended to minimise these results; (3) the use of small overflows ($\frac{1}{8}$ the volume of the test piece cavity) were ineffectual; (4) the use of large overflows tended to minimise but not eliminate the effects of the trapped air and turbulence; (5) when molten metal was forced into a die cavity through large gates at slow rates of injection without the aid of vents or overflows—(*a*) turbulence was reduced, (*b*) mechanical properties improved, and (*c*) blistering was reduced; (6) when overflows and vents were added (*a*) the blistering disappeared, and (*b*) the mechanical strength made enormous increases.

To-day the writer produces commercial, high quality pressure die castings, called "pressure mouldings," which have superior mechanical properties in the as-pressure-moulded state and which may be heated to elevated temperatures without blistering or distortion—these pressure mouldings are made in accordance with the findings mentioned above.

It now seems likely that the future of the pressure mouldings will be brighter, since they will be more extensively employed by designing engineers, who have refrained from employing pressure die castings because of their low ductility and inconsistent mechanical properties. Pressure mouldings are already competing from an engineering standpoint, as well as in cost, with heat-treated sand and permanent moulded castings of aluminium-base alloys. Even in comparison with grey iron castings the cost may be favourable to the pressure-moulded aluminium-base alloy casting as indicated in the example illustrated in Fig. 1.

## Anodic Oxidation of Aluminium and Aluminium Alloys

THE introduction to this publication begins with a brief historical note and continues with an account of the mechanism of the formation of the anodic film. The effect of alloying elements on the current density and appearance of the film is then described and there is a paragraph on the special problems arising in connection with the anodising of castings. The next section of the book describes procedures such as preparation, racking of articles, sealing and cleaning the anodic film which are common to all anodising processes. The three main processes (i.e., chromic acid, sulphuric acid and oxalic acid processes) are first compared and then the plant required, operating conditions and appearance of the film produced are separately described.

There is a considerable section on the special subject of the dyeing of anodised aluminium which deals with the suitability of films for dyeing, compares the results achieved on films produced by the three main processes and then describes dyeing procedure including information concerning available dyestuffs.

Other sub-sections describe dyeing with inorganic salts, the production of special effects including multi-colour effects, direct printing and photographic processes. The main text of the publication is concluded with two sections, one on the general characteristics of anodic films and the other describing the important process of electrolytic brightening which has as a typical application the production of searchlight reflectors in superpurity aluminium electrolytically brightened and anodised. Appendices deal with anodising bath control, methods of conducting various tests and selected bibliography.

Information Bulletin No. 14, published by The Aluminium Development Association, 33, Grosvenor Street, London, W.1. Price 1s.

DAVID BROWN & SONS (HUDDERSFIELD), LTD., announce that with effect from 31st July, 1948, their London Office occupies premises on the ground-floor of Bush House, Aldwych. Telephone Number is TEMple Bar 0867, 0868 and 0869 .

# Machine Tool and Engineering Exhibition

## held in Olympia, London

*The passage of fourteen years since the last Machine Tool Exhibition has shrouded many of the developments in this industry with a cloak of near secrecy. The renewal of this series of exhibitions is therefore of considerable concern to manufacturing industries since machine tools are called upon to play a vital part in solving the problems associated with increased production. Some interesting exhibits are briefly described in this pre-view which has been prepared not only to assist readers visiting the Exhibition, but those who, for various reasons, are unable to attend.*

THE Machine Tool and Engineering Exhibition, which opens at Olympia, London, on August 26 and continues until September 11, is mainly concerned with machine tools and, in this respect can be compared with the Exhibition held fourteen years ago; as far as the exhibits are concerned, however, great changes will be evident since considerable developments have been made in the design and performance of machine tools. Not only are improved types of machines included, but entirely new ranges of machine tools have become available.

Although many foreign machine tools will be on view they are largely of a specialist character and the most outstanding feature will prove to be the design and performance of the exhibits of the British machine tool industry. Many will remember the difficulties experienced by this industry after the 1914–18 war and there was a fear that a repetition might occur after this last war. There was justification for this fear, because, during the war, the industry was manufacturing far in excess of peace-time requirements and the output of machine tools from British works, together with retained imports of special machine tools from overseas represented a fantastic accumulation of machine tools judged by any peace-time standard. Discussing the future of this industry several years ago we suggested that "the greatest machine tool exhibition the world has ever known should be held in London—not in Leipzig or Cleveland—at the earliest possible moment after the war, and our sales forces should be on the world's doorsteps before the defeated and occupied countries have time to draw breath. We must be ahead of former enemy and former ally alike; ahead, not only of Germany, Italy and Japan, but of Belgium, France, Norway, Czechoslovakia, Russia and—why not?—of America too."

It is not suggested that the forthcoming Exhibition will be the greatest the world has known, but we are quite sure that the majority of home and overseas visitors will be agreeably surprised with the new machines the British machine tool industry has developed and with the quality of workmanship applied in their design and construction. At this Exhibition are the tools industries need to support their bid for the world's markets. Behind every manufacturing activity is the machine tool and success or failure of a particular manufacture will depend, in a large measure, on the capacity and efficiency of the machine tools used. The British machine tools on view will compare favourably with any and the industry, in giving effect to a planned commercial effort, has substantially reduced the difficulties experienced during the period following the 1914–18 war.

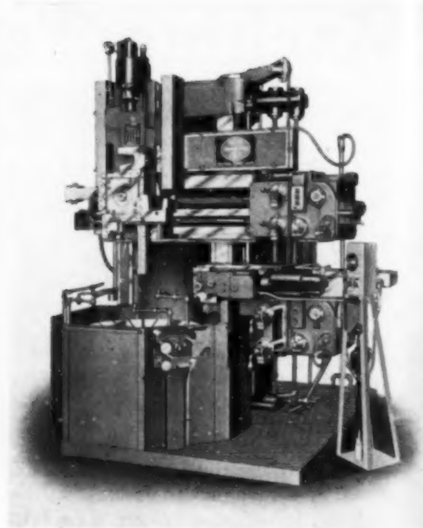
Lack of space prevents other than a brief reference to some of the exhibits, but they are given with a view to assisting readers who will be visiting the Exhibition and especially those who, for various reasons, are unable to journey to Olympia. For convenience, typical examples of machine tools, cutting tools, heat-treatment equipment, and miscellaneous exhibits, are reviewed under their particular headings.

### Machine Tools

**The David Brown Machine Tools Ltd.,** Stand No. 131, in the Grand Hall, is that firm's first public exhibit since it undertook a comprehensive modernisation scheme and changed its name from Muir Machine Tools Ltd. on entering the David Brown organisation; and not only is it of considerable interest as the first shop window of the latest David Brown undertaking, but it possesses a particular importance as showing the efficacy of modern conceptions of wholesome design applied both to well-established machines and to new models.

Three of the well-known range of moving table hobbing machines are exhibited, including the new stream-lined 15-in. machine, and it is gratifying that the "new look" is attracting substantial business from the Continent. This essay into industrial design has brought the advantages of greater rigidity under high-production stresses and an improved accessibility for quick setting up and easy cleaning. Shown for the first time is the David Brown S25 gear shaving machine, a notable addition to the David Brown "Muir" range of precision machines. It will satisfy a long-felt need for a British machine of this type. Its modern lines have set up a new standard of accessibility to the change gears, for their total enclosure has been effected in such manner that the machine can be very easily cleaned in spite of the fact that the change gears are automatically lubricated. The gear shaver corrects spur and helical gears to precision limits of accuracy of tooth profile, tooth spacing and helix angle, by the shaving process. A range of machines covering all sizes of gears up to 25 in. diameter has been developed. It is noteworthy that an automatic tooth-relieving mechanism (patent applied for) carried on the cutter slide enables gear teeth to be crowned, tapered or thinned down at the ends as required, by feeding the cutter deeper into


**The re-designed David Brown Machine Tools, Ltd. MT15 hobbing machine which makes its first appearance at the Machine Tools Exhibition**



**A Bullard Man-an-trol vertical turret lathe; an automatic capable of 39 functions, shown by Buck & Hickman.**

mesh with the work at pre-determined positions governed by the setting of adjustable cams carried on the upright of the machine.

Sharing in interest with the gear-shaver will be the MT 15 hobbing machine, which also is making its first appearance on the market. It is the smallest machine in the moving table series, with a capacity up to 15 in. diameter. Conventional or "climb" hobbing can be used without any adjustment, while quick power traverse is provided for hob slide and table. The standard hob slide, of normal design, has hardened and profile-ground single helical gears for the hob spindle final drive. An interchangeable universal traversing hob slide with tangential feed is available having 360° swivel, which permits the production of both 90° and angle worm gears. Spur and helical gears within a slightly restricted range can also be cut with this attachment.

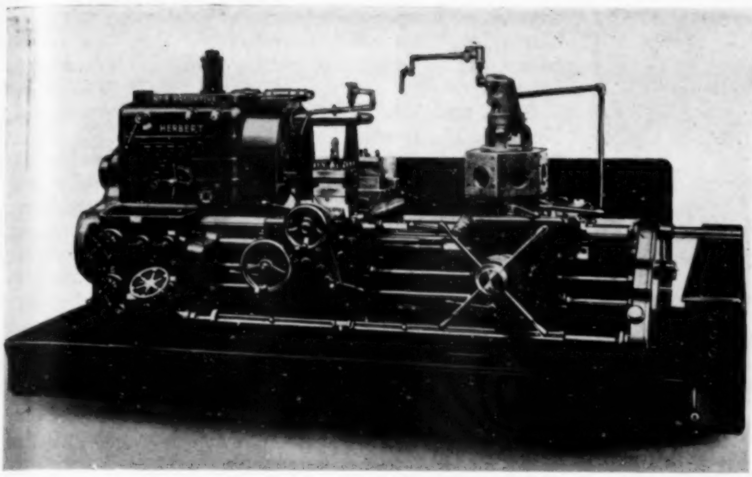
The intermediate machine in the moving table series the MT 30, will cut gears ranging from 2 in. to 30 in. diameter. This also is a substantial machine of great rigidity, possessing a large diameter table and robust hob slide, enabling it to be worked to maximum capacity without loss of finish or accuracy. In general design similar to the MT 30 is the MT 60, a powerful machine for generating gears of 6 in. to 60 in. diameter up to 1½ in. circular pitch. In common to all three of the MT range, particular attention has been given to the accessibility of the totally enclosed change gears for hob speed, feed, spiralling and indexing.

**The Churchill Machine Tool Co. Ltd.** are showing typical examples of their wide range of precision grinders and particular attention is directed to a new Churchill machine designed for high production grinding of crankpins on automobile and similar types of crankshaft up to 36 in. long and requiring a maximum swing of 14 in. This machine is built to tolerances considered fine even in the machine tool industry, and it incorporates many features already tried and proved over a period of many years, including hydraulic withdrawal and forward movement of wheelhead with diminishing feed, wheelhead movement interlocked with spacing control, "Hydrauto" spindle bearings, double-end drive to workheads, automatic withdrawal of steady as the wheelhead withdraws. New features include automatic electric clamping, wheel truing with work in position, control mechanism in accessible position on the front of the machine and an entirely new design of body which avoids distortion and rigidity is obtained without excessive weight.

**A. C. Wickman Ltd.**, Stand Nos. 28, 203 and 26, in the National Hall, occupy a total floor space of 9,000 sq. ft. to accommodate the wide range of machines and equipment shown. Over 60 machines will be on view on three stands, these include the Wickman range of multi- and single-spindle automatics; an entirely new range of grinding and lapping machines; the latest versions of applied high frequency induction heaters; Cornelius electronic comparators; and Wimet tungsten carbide.

New developments on Stand No. 28 include the Wickman 5-spindle bar automatic which is now available in ⅝in. capacity, while a newly designed swarf conveyer is available in this range of machines. Several Hauser machines are shown on Stand 26, and particular attention is directed to a new Hauser combination jig borer and jig guider just introduced which promises a wide appeal in medium sized establishments where individual machines are not justified. Many visitors will be especially interested in a multi-spindle automatic on which will be demonstrated a self-energising thread rolling attachment designed to move radially into a work piece and to release immediately on completion of the operation. A flat generating attachment for multi-spindle automatics will also be shown, producing square, hexagonal or octagonal flats by generation.

Many of the continental and American machines for which A. C. Wickman are agents, are being exhibited, but many British machines for which this Company are sole agents will also be shown, including Webster and Bennett boring and turning mills, Chatwood hob grinders, Neven grinding and lapping machines and diamond wheels. Ryder verticalautos and Ryder piston ring machines are being shown on the Ryder Stand No. 101, and Planers (Huddersfield) Ltd., have a range of their well-known planers on their Stand No. 162. The versatility of Ryder automatic vertical lathes will be demonstrated by the production of components requiring multi-drilling and turning between centres. It should be noted that the Ryder forging machine is now available in a new streamlined design and will be shown.



**The Herbert patent preoptive headstock.**

**Alfred Herbert Ltd.** occupy four stands, but Stands Nos. 1 and 12 are those on which machine tools by leading British, American and Swiss are exhibited. Since the last machine tool Exhibition in 1934, this Company has introduced a number of new machines embodying revolutionary changes in design. There has been a continuous effort to increase the efficiency and durability of Herbert machines—higher and increased range of speeds, and feeds, reduction of idle time and ease of operation, all factors tending to increase production and durability. As cutting times are reduced the reduction of idle time becomes increasingly important. The Herbert patent preoptive headstock, introduced in 1936 is claimed to be the most revolutionary development in headstock design since the introduction of the single pulley head. Idle time due to speed changing is eliminated, the operator pre-selecting any required speed by turning a dial and engaging the speed, when required, by finger pressure on the knob in the centre of the dial, the entire operation being performed while the tools are cutting. This preoptive headstock is now power-operated and is being fitted in an improved form to several lathes.

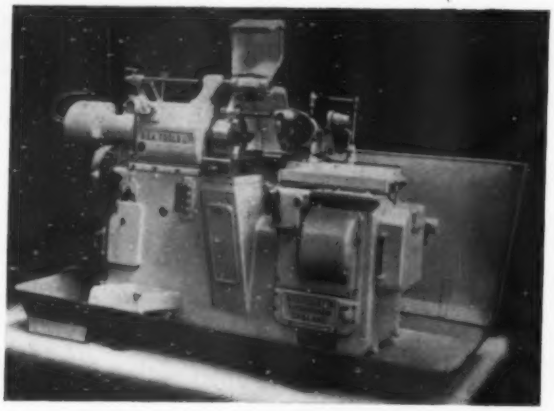
Electrically-operated chucks can be fitted to Herbert lathes—jaw chucks on the capstan and turret lathes and double-toggle chucks on the hexagon turret lathes. This type of chuck is easy to operate without fatigue, chucking is extremely rapid and power consumption is very low, current only being consumed during the opening and closing operation. It requires no auxiliary equipment for its installation since it is coupled direct to the electric mains. Mechanism is self-locking and centrifugal force has no effect on the jaws. Other refinements include: improved spindle mounting; centralised controls and general ease of operation; quick-power traverse to save time and relieve the operator of physical effort; power-operated fixtures and chucking devices, pneumatic or electric, to provide further relief to operators; self-contained built-in electrical equipment; and power transmission gears hardened and ground, to suit the high speeds required when using carbide tools and trend towards quiet running.

**Arthur Scrivener Ltd.** The ingenuity and resoucefulness of the machine tool industry is well shown by the large number of fully automatic machines and it is probable that no section has received more attention in this respect than centreless grinding machines. The controlled-cycle centreless machine, which has been evolved by this Company lends itself particularly to automatic operation, and the numbers of extremely interesting magazines have been developed by means of which the whole feeding and grinding operation becomes entirely automatic, apart from the necessity of keeping the magazine periodically supplied with workpieces. One of the most spectacular of these automatic installations is the No. 2 centreless grinder with automatic rotary hopper which will be exhibited. This type of hopper is employed for feeding small cylindrical pieces which are ground on the centreless machine by the straight-through method at such amazing rates of production as 10,000, 20,000 and even 30,000 pieces per hour to close limits of accuracy. These combined units have been particularly effective in reducing costs of production (particularly labour charges) in the case of small cylindrical work such as pins, rivets, etc., for chain transmissions, rollers, valve tappets, and even the small carbon sticks which constitute the element in electric dry batteries.

The automatic grinding of form work presents greater difficulties than plain cylindrical pieces, as not only has an in-feed movement of the wheel and piece to be provided for, but there is also the difficulty of loading an awkward piece on to the workplate between the wheels and its subsequent ejection. For the automatic loading of the piece, the firm has developed eight different types of magazine to cover pieces of varying degrees of complexity the type which is shown in operation on the stand being the magnetic type working in conjunction with No. 2 patent controlled-cycle centreless machine.

Among the many exhibits on this stand is the No. 1 profile turning lathe, which is a machine for producing cams on camshafts and similar copy-generating work by means of special shaving-cut tools. The machine exhibited is tooled for an 8-lobe camshaft for a 10h.p. engine, the cams being machined in a floor-to-floor time of 3 mins. Apart from its wide application to camshaft work, the same machine can be used for producing rapidly and economically a wide variety of profiles.

**Burton, Griffiths and Co. Ltd.** show, on Stand No. 112, Grand Hall, a wide range of machines including an abrasive No. 5 AWF internal finishing machine for grinding and finishing carbides and similar materials for dies, gauges, and bushings; an abrasive model GC circular graduating machine; a Gardner No. 125 double ended disc grinding machine; a Gisholt vertical head simplimatic automatic lathe; a Gisholt 31 S dynetric balancing machine; a Landis 5 in. type DH hydraulic cam grinding machine; a Landis 16 in. $\times$ 42 in. type DH hydraulic crankpin grinding machine; a Maag PH 60 gear testing instrument; a Maag internal gear grinding machine; a National Acme Gridley 1 in. model RA 6-spindle automatic bar machine; a National Acme roll-matic thread and form rolling machine; all of which will be shown in operation.



**The new B.S.A. 9-in. single-spindle automatic chucking machine.**

**B.S.A. Tools Ltd.** On Stand No. 46, National Hall, several machines will be shown in operation including Nos. 48, 68, 88 and 138 single spindle automatic screw machines; a B.S.A.-Acme Gridley $1\frac{5}{8}$ in. BRT 6-spindle automatic bar machine; 5 in. and 9 in. single spindle automatic chucking machines; a B.S.A. 5D Potter and Johnson power flex automatic turret lathe; 6 in. × 12 in. and 6 in. × 20 in. multi-tool production lathes; and Nos. 7 and 8 centreless grinding machines.

The 9 in. single-spindle automatic chucking machine is a new machine which incorporates many improvements. In this machine electrical control now supersedes mechanical control, making for a cleaner design; the fast or idle motion is operated by a small specially arranged motor mounted at the rear of the cross slides; the speed gearbox is situated at the back of the head stock, giving more space at the front of the machine. It is still designed for two automatic speeds, but these may now be changed under cut. Easy accessibility is given to the drums controlling the speed and feed; hardened ways are provided for the turret slide; and the spindle speed is increased and also length of feed travel.

**Taylor, Taylor and Hobson, Ltd.,** on Stand No. 7, National Hall, are showing several engraving and die-sinking machines. Among these is a hand operated pantograph milling and die-sinking machine for machining complex surfaces, producing all forms of dies, moulds, contours and irregular forms, such as plastic moulding dies, drop forging or hot pressing tools, etc., comprises a high-speed vertical milling spindle, coupled to a tracer by a patented pantograph arrangement, the motion of the cutter following exactly and accurately the flow of the tracer, both horizontally and vertically.

Considerable interest will be centred on a new chasing lathe which has been primarily developed for second operation work dealing with parts cut from the bar or tube, or with individual castings. The spindle carries at its rear end, a master lead screw which automatically engages with a half nut (buttress thread) at the end of each stroke, the whole of the spindle rocking on a shaft in and out of engagement by means of an eccentric with suitable tripping devices. The feeding screws have drums at the handle end with a series of stop plates each of which is independently adjustable, and engages with separate triggers. The stop being on the handle itself, there is no straining of the screw or the frame of the machine, with possible variations in sizing.

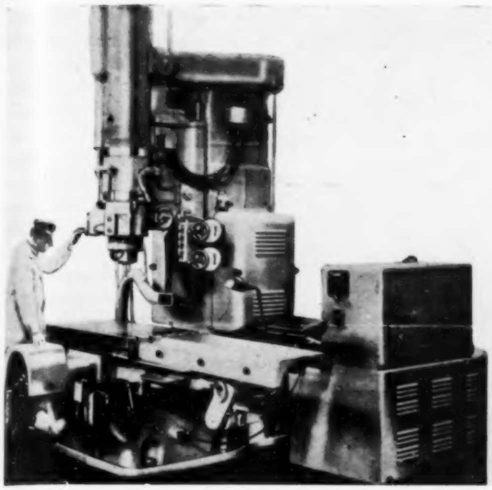
**Buck and Hickman Ltd.** are exhibiting on Stands Nos. 15, 16, 18 and 19 in the National Hall. Those machines selected for display include No. 00G automatic screw threading machine; automatic pinion turning machine; No. 13 universal and tool grinding machine; and No. 12 universal grinding machine by Browne and Sharp. The Bryant No. 107 AW internal grinding machine and a Bryant No. 109 automatic internal grinding machine. The Bullard Man-au-trol tracer mounted on an Archdale radial drilling machine. Other Bullard Man-au-trol models include a vertical turret lathe and also a 30-H 3-spindle horizontal lathe. The former is an automatic capable of 39 functions without cams or similar wearing parts, without human or cumulative error. Instant conversion to manual operation and return to automatic operation without affecting the tooling sequence, cuts production costs to the minimum.

The exhibits will include 10 Gleason machines; a National $\frac{1}{8}$ in. long stroke double blow solid die cold-header, which is one of a range of similar machines from $\frac{1}{8}$ in. to $\frac{3}{4}$ in. designed for producing machine bolts, cap screws, and other work; and two Pratt and Whitney machines, one an all electric jig grinder and the other a universal die sinker. The jig grinder is a machine for grinding holes to jig borer spacing tolerances it being a companion to the Pratt and Whitney jig borer. It is equipped with interchangeable electric wheelheads covering a full range of holes up to 5 in. diameter.

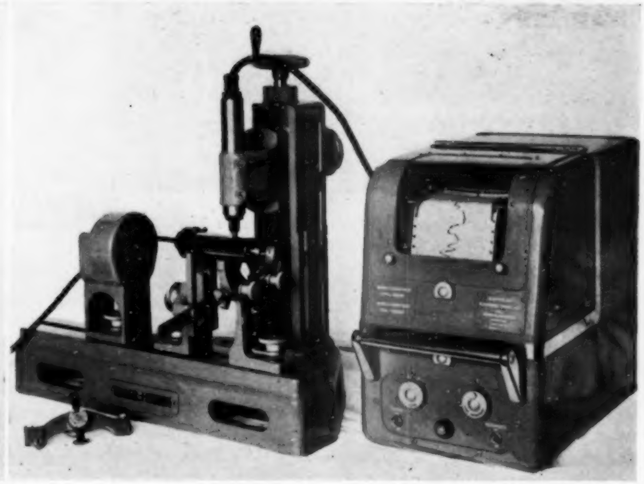
**John Holroyd and Co. Ltd.** are showing a typical example of special machine tools which they design and manufacture to suit individual requirements. It is a slab milling machine and is designed for gang or face milling. The cutter spindle is of high carbon steel carried in an adjustable sleeve and revolving in taper roller bearings. The drive to the spindle is through enclosed gearing and pick-off gears for speed variation from a constant speed motor, a reversing switch being provided to reverse the direction of rotation of the cutter when necessary. The cutter headstock, which is balanced, is provided with vertical adjustment by hand. The overarm can be moved clear of the work when using face milling cutters. The support column can be lowered below the level of the table and can be locked in any position. The table is tee-slotted for clamping bolts; it has power feed and quick return, adjustable automatic trip and hand traverse; the feed drive is from a constant speed motor through gearing and pick-off gears for variation.

Other machines on view will include an oil grooving machine, specially designed for cutting various types of internal and external oil grooves in bushes, on shafts or similar work; an automatic thread milling machine designed for semi-automatically milling multi-start external thread components by means of a single cutter; and a woodworkers' tool grinding machine, which is designed to sharpen every tool in the woodworking and patternmaking shop except the saw.

**George H. Alexander Machinery Ltd.** will show a line of machines for producing bolts and nuts by the cold process. They will include heading, thread rolling, slotting and bolt head trimming machines, also machines



A Pratt & Whitney all-electric jig grinder shown by Buck & Hickman.



The Taylor-Hobson "Talysurf" surface meter for measuring the texture of surfaces.

for pointing bolts prior to the thread rolling operation. One of the heading machines is a machine of an entirely new range. This is a long stroke solid die high production machine capable of producing $\frac{1}{4}$ in. $\times$ 3 in. bolts at the rate of 175 per minute. It is noteworthy that this machine will have attached to it the Ajax Hogue wire drawing attachment, whereby "black" rod will be fed into the Ajax attachment, drawn down and fed directly into the heading machine at the same rate at which it is headed, thus enabling black rod to be used, whereas the normal practice is to feed in drawn wire. The advantage, of course, is that the black material is very much cheaper, and secondly, whereas wire drawn in the ordinary way, and used a considerable time after it has been drawn, age-hardens and makes the heading operation much more difficult, this is not so when the material is fed directly into the header immediately following the drawing operation.

Other exhibits will be a standard line of broaching machines, a Radiac abrasive cutting-off machine automatic nut tapping machines, one of which will be of the very latest type, inasmuch as it incorporates a straight shank stationary tap. The nut tappers will cover a range from the small B.A. sizes up to and including $\frac{5}{8}$ in. bolt size.

The well-known line of three-dimensional die-sinking and engraving machines will also be exhibited and the universal tool milling machine which this firm calls the master toolmaker; a range of honing equipment; and optical equipment.

**Stuart Davies Ltd.,** on Stand No. 282, Empire Hall, are showing a bar or tube rolling machine which is a departure from the usual type of machine in that it is powered by two driving motors instead of one. Machines of this type consist of a pair of rolls mounted in housings having suitable adjusting gear, so that during the passage of the material through the rolls it is suitably deflected to remove deformation thus producing a straight bar or tube. Due to the rolls being shaped to concave and convex profile, it is apparent that considerable slip must take place at different points on the rolls and this also varies for different sizes of materials. The advantage therefore, of driving each roll from a separate motor is that most of the slippage can be taken care of in the motors themselves, the effect of which is to remove the stresses set up in the gears and other working parts of the machine. Wear of all working parts of the machine is, therefore, reduced to a very considerable extent and the machine is practically silent in operation.

Speeds up to 80 ft. per minute are usually recommended, although the question of speed should be determined according to the type of material being straightened. Generally speaking, higher tensile materials respond better to a slow rate straightening, whereas softer materials can be straightened at much higher speeds, in fact, even faster than 80 ft. per minute if required. These machines are available in a full range of sizes for dealing with materials from $\frac{3}{16}$ in. up to 6 in. The machine exhibited will cover the range $\frac{3}{16}$ in. to $\frac{5}{8}$ in. diameter.

**Rockwell Machine Tool Co., Ltd.** are exhibiting on several stands. On Stand No. 87, Grand Hall, are two "Giddings & Lewis" machines, one being a No. 570T high-power, precision, horizontal boring, drilling and milling machine of the table type; the other is a 230 portable horizontal boring, drilling, milling, tapping and facing machine. There will also be a "Kaukauna" No. 125U portable horizontal boring, drilling and tapping machine and four "Monarch" machines. The latter include the "Shapemaster" engraver, the "Mona-Matic," the EE super-sensitive precision tool makers' lathe, fitted with "Monarch" patent air tracer, and the model 60 precision tool makers' lathe.

On Stand No. 153, Empire Hall, are shown the "Sundstrand" No. 53A double-end drilling and centreing machine, and an "American" type T8/24 patent three-way broaching machine. Then on Stand 165A in the same Hall will be exhibited a "Cincinnati Bickford" super-service, high-speed, high-power 5-ft. radial drilling machine; a "Rockford" 24-in. special hydraulic shaper and a "Rockford" 36-in. openside hydraulic shaper; and two "Thompson" grinders, one being a type F "Formanoid" surface grinder, and the other a "Truform" crush form contour grinder.

On Stand No. 264, Empire Hall, are exhibited two

**The " Dormer " screw extractor by The Sheffield Twist Drill Co., Ltd.**

" Taft-Pierce " machines, a 6-in. rotary grinder and a precision horizontal surface grinder; an " Avey-Draulic " sensitive drilling unit with torque-matic control; and a " Le Blond " 17-in. regal lathe with electric contouring attachment. Also shown on this stand are V.S.G. hydraulic variable-speed transmission gears, for all purposes where steplessly variable and positive speed control is necessary; V.S.G. variable delivery pressure pumps for controlling the operation of hydraulic machinery; V.S.G. vane-type pumps for small constant deliveries—these are a recent development; and V.S.G. hydraulic valves.

### Cutting Tools and Materials

Although early difficulties encountered with hard metal tools still linger in the minds of some production engineers, it is generally recognised that these difficulties have been largely overcome. Slight modifications in the alloys employed, developments in machine tool design and improved technique on the part of operators, have combined to make great improvements in cutting operations, not only increasing cutting speeds but in improving the quality of finish and in obtaining longer service from the tools. The capacity of various tools will be demonstrated on many stands.

**Firth Brown Tools Ltd.** will demonstrate their carbide tools; their exhibits will include a representative range of their standard products, which includes twist drills and reamers; milling cutters, end mills, etc., of all types; " Zeelock " patent inserted blade cutters; the new type 3 face milling cutter with " Mitia " carbide tipped teeth; ground thread taps and chaser dies; the many applications of " Mitia " carbide, including wear resisting parts and coal cutter bits, etc.; " Speedicut " high speed steel and " Die-Hard " tungsten alloy steel hacksaw blades; shear blades and machine knives; engineers and saw files; " Millenicut " and " Dreadnought " milled tooth files; circular woodsaws; circular saws tipped with " Mitia " carbide for plastics; " Insto " segmental cold saws; and precision tools for the clock, watch and instrument industry.

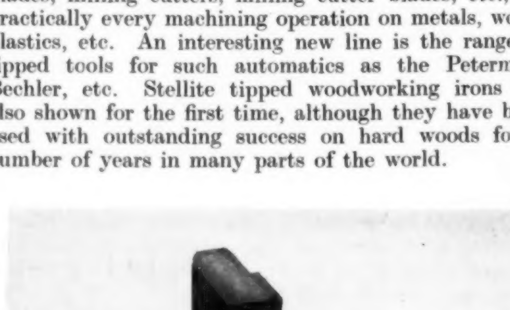
**Edgar Allen and Co. Ltd.** Of special interest is a display of the value of the " Athyweld " process by this firm. Some 15 difficult special steels will be shown welded together and to one mild steel back by this process. It is believed that a total number of 120 steel combinations is made possible by this modern deposit welding process, giving carbon control, purity and dimensional accuracy. Also are shown Athyweld woodworking knives such as planing knives, block knives, tonguing and grooving knives and rebate cutters.

The advantages of this process as so applied are as follows: (1) Safety, as the hardened cutting medium is electrically deposited and firmly welded to the mild steel backing. Accidental damage to the tool will cause the edge to splinter, rather than a large piece to fly out with danger to the operator; (2) A wide range of cutters is made and special cutters can also be made; (3) Almost any grade of steel can be welded to a tool body of good quality steel so that the deposit, e.g., high speed steel, becomes an integral part of the parent metal; (4) Almost any type of steel can be deposited, so that a quality failing to give the desired result can be replaced by a different material, e.g., cobalt chromium alloy.

Various types of other Athyweld tools such as wool combs, knurling knives and crop shear blades will also be shown. The shear blades are an interesting exhibit because they show how two deposits can be laid in; one on either side of the blade to make a double-edged shear blade, where normally solid high-speed steel would be used. The blades have actually been used in service with full satisfaction. In addition, a wide range of Stag Athyweld precision machine ground tools will be shown, and there will also be representative displays of Allenite tungsten carbide tools and tips; Stag high speed steel cutters, reamers and end mills; Stag Athyweld parting and other simple type tools; Stag Major toolholder bits; Stag Major Superweld electrically butt-welded hand-ground tools, as well as a display of machine-ground form tools in high-speed steel and tungsten carbide. Some steel castings will also be shown.

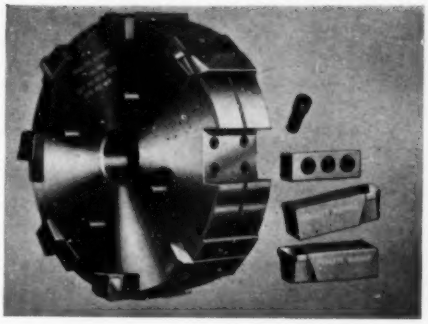
**A. C. Wickman, Ltd.,** have established a complete tool service at Olympia for the duration of the Exhibition. A large stock of tools covering all operations performed by their machines will be displayed on the Wickman " Wimet " Stand No. 203.

**Deloro Stellite Ltd.** are exhibiting a wide range of grade 100 Stellite toolbits, tipped tools, parting-off blades, milling cutters, milling cutter blades, etc., for practically every machining operation on metals, wood, plastics, etc. An interesting new line is the range of tipped tools for such automatics as the Peterman, Bechler, etc. Stellite tipped woodworking irons are also shown for the first time, although they have been used with outstanding success on hard woods for a number of years in many parts of the world.



**Turnings obtained with an " Ultra Capital " high-speed steel in the form of a solid tool for tyre turning.**

A grade 100 tool will be demonstrated cutting at red heat, to show that its cutting capacity is unaffected by such temperatures as 900°–950° C. On another lathe, grade 100 tools will be seen turning high-tensile steel. Although conditions will not permit of working to its full cutting capacity, a good idea of the metal-removal powers of Stellite is given by various samples of high-tensile steel, one of which represents a depth of cut of $1\frac{1}{4}$ in., turned with a feed of 0·084 in. at 60 ft./min.



**Reversible cutter by Protolite, Ltd., showing left- and right-hand blades.**

Stellite drills will also be demonstrated drilling files, hardened dies, etc. The display also includes a practical demonstration of hardfacing by the oxy-acetylene process, while many examples of hardfacing, representing practically every branch of industry, give a good idea of the very wide scope of Stellite hardfacing.

**The Sheffield Twist Drill & Steel Co., Ltd.** are showing representative ranges of their standard products —i.e., high-speed steel twist drills, reamers, end mills and similar small tools. Of considerable interest is the range of " Dormer " screw extractors made by this Company.

These extractors provide a ready means of removing broken screws without resorting to chipping. All that is necessary is to drill a hole endwise in the screw, insert the largest possible size of extractor and, using a tap wrench, turn in an anticlockwise direction. The corkscrew teeth bite into the screw and removal can be effected without damage to the thread in the hole. Seven sizes of extractor are available, covering screw sizes ranging from $\frac{1}{8}$ in. to 1 in. diameter, the size of drill used for the preliminary operation varying from $\frac{5}{64}$ in. to $\frac{17}{32}$ in. diameter.

**Protolite, Ltd.,** Stand No. 213, National Gallery. Specialisation has always been an important maxim in the development of the use of cemented tungsten carbide by this Company, and the extended use of this material to meet specific requirements in various manufacturing processes is well illustrated by recent additions to the range. For example, " Prolite-Nurake " milling cutters have now been redesigned to enable the bodies to be used for both right and left hand cutting merely by changing the blades, replacement blades being supplied mostly from stock.

For a number of years Protolite, Ltd., have been supplying solid steady bushes with cemented tungsten carbide inserts, the wear-resisting properties of which materially increase the efficiency of the automatic machines on which they are used. Split steady bushes and feed fingers with carbide inserts have now been introduced to meet the particular requirements of precision industries, more especially the instrument and watch and clock making industries. They are available in a wide range of sizes for Petermann, Bechler, Tornos, Brown and Sharpe and Wickman machines.

Textile manufacturers have recently welcomed a wide range of looped wire parts (twissels), made from cemented tungsten carbide in diameters of from approximately 1 mm. to 6 mm., to form thread guides in various weaving and fabricating processes. Here again the advantages of this highly wear-resistant material when applied to jute, hemp, flax, asbestos and other abrasives substances is immediately apparent.

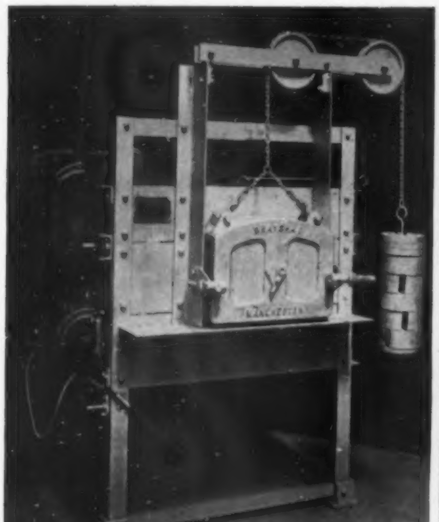
**General group of Prolite tungsten carbide products.**

The use of cemented tungsten carbide for the wearing parts of dies is already well established. The range of " Prolite " dies and press tools includes wire, bar, and tube-drawing dies, and tube-drawing plugs, briquetting and tablet machine dies, rivet heading dies, welding rod coating dies, metal-forming dies, etc. All the foregoing items, together with many others available, will be on view and demonstrations of the use of turning tools and milling cutters will be given.

**The Brooke Tool Manufacturing Co., Ltd.,** on Stand No. 237, Grand Hall gallery, exhibit the complete range of their cutting tools, comprising high-speed steel milling cutters of all types including slotting cutters, plain milling cutters, side and face cutters and facing cutters, also end-milling cutters, including slot drills, etc.; gear cutters, hobs and other form-relieved cutters; and metal slitting saws, both hollow-ground and with side chip clearance. Also exhibited is a full range of reamers, including expansion and adjustable types also high-speed steel twist drills both taper and straight shank.

In addition to the above are shown the " Cardinal " bladed milling cutters and inserted blade-facing heads, " Cardinal " drill chucks and rapid slip drill chucks, gear pumps for suds and oil, tapping attachments, counterboring sets and machine vices, both cam and screw action. A number of tools manufactured to suit various special requirements in the engineering and allied trades are also shown. These are of interest as showing the range and quality of such work which this Company undertakes.

**Arthur Balfour & Co., Ltd.** on Stand No. 207 will show an interesting range of exhibits including " Balfalloy " hard metal tipped boring heads, and " Ultra Capital " high-speed steel tangential tools. Representative types of various engineers' small tools this firm supplies for modern production are also shown such as angle cutters, butt-welded tools, chasers, chisels, chucks, counterbores, countersinks, drills, end mills, form tool, gear cutters, gear hobs, hacksaw-blades, hacksaw-frames, lathe centres, plain mills, punches and dies,



**Brayshaw "Lopress" recuperative oven furnace.**

**A gas-fired twin chambered high-speed steel furnace.**

reamers, rotary boring bits, setts, side and face cutters, slotting cutters, slot drills, sockets, tool bits, etc.

In addition to displaying various qualities of high-grade carbon steels, high-speed steels and alloy steels for all purposes, including special steels for moulds, press tools, dies, gauges, etc., they are exhibiting special tools which have been manufactured by customers from their steels. They are also displaying many interesting components which have been produced by their tools.

Some of the greatest strides they have made in recent years have been concerned with the development of hard metal, and consequently "Balfalloy," which is available in the form of tips or tipped tools, is now famed throughout the world as a metallic carbide, whose principal characteristic is a combination of extreme hardness and toughness—a feature which ensures longer life between regrinds.

One of the many successful uses of "Ultra Capital" high-speed steel is in the form of solid tools for tyre turning. These particular tools operate on railway steel tyres which have been work-hardened by braking and which present an exceptionally severe test for any cutting tool. The turnings, shown in an accompanying illustration which were obtained when operating at 12/15 ft./min., $\frac{5}{16}$ in. to $\frac{3}{8}$ in. depth of cut, with 0·30 in. feed, are a testimonial to the excellent cutting capabilities of this material.

**Buck & Hickman, Ltd.,** in addition to their exhibits of machine tools, are showing a wide range of engineers' tools and equipment displayed on Stand No. 219 in the National Hall gallery. These tools and equipment cover the requirements of all the products of such British and American tool manufacturers as Beaver, Brown & Sharpe, Cushman, Desoutter, Eclipse, Millers Falls, Monitor, Morse, Oster, Parkinson, Pratt, Pratt & Whitney, Record, Roebuck, Toga, Universal, Williams, Woden, etc.

**Samuel Osborn & Co., Ltd.,** Stand No. 225, National Hall gallery, have been making high-grade steels and tools for nearly a 100 years and at previous exhibitions have usually demonstrated the cutting power of their tool steels with heavy machine tools; at the forthcoming Exhibition, however, they not only show the steels and tools produced, but also the methods adopted in their production. The theme of the exhibit is "from the steel to the finished product." It takes the form of a large revolving ring, on which are displayed the various tools which are produced by the company, and inside this ring are three panels on a built-up stand. The first panel is a model of an arc furnace melting shop showing a furnace melting and tapping steel into a ladle and making the ingot. The second panel shows these ingots which pass to the forge being processed and consists of a working model of a forge shop and illustrates how the ingots are forged into blooms and billets ready for further processing in the rolling mill which is shown in the third panel consisting of a train of rolls in operation complete with all accessories.

Steel bars and blanks produced by the processes as shown in the panels are the raw materials for the various stages of the production of tools shown on the outer ring itself. The wide range of steels shown include the famous "Mushet" range of high-speed steels and subsequently improved grades for the highest performance, such as S.O.B.V. cutting alloy, S.O.1221 and Super Mushet 723. These are shown together with a display of twist drills, milling cutters, reamers, hobs, lathe tools, toolholder bits, etc., which are made from the range of special steels mentioned.

**Hall & Pickles, Ltd.** will have an extensive display of form-relieved profile cutters used for machining turbine blades and ancillary equipment, which will attract a good deal of attention. There will also be a fine selection of "Hydraloy" hard metal tipped tools such as stepped boring tools, core drills, tangential and flat form tools, tipped side and face cutters, face mills and many others. Another interesting section will be a display of Hydraloy tipped percussive drill rods and bits for drilling hard rock, and rotary drill bits and rods for coal cutting will have topical as well as technical interest. The tools exhibited are made from this firm's brands of high-speed steel, "Double Super Hydra" and "Super Hydra."

### Heat-treatment Equipment

Heat-treatment operations in the toolroom and workshop have developed in recent years largely as a result of improvements in the design of equipment and in heat-treatment technique which enable much closer control. More and more is the trend towards placing facilities for heat-treatment in the production line and for many purposes the heat-treatment plant may be regarded as a machine tool operating either fully or semi automatically.

Although the larger heat-treatment furnaces are usually illustrated by photographs on many stands, there are excellent examples of smaller types which indicate progress in this field.

**Birlec, Ltd.** on Stand Nos. 142A and 143, will confine their exhibits to special models and photographic displays of three of the most important phases of electric furnace design—gas carburising, copper brazing and induction heating. Virtually, gas carburising is a new development since it has not long been utilised as a production process and this vastly improved case-hardening procedure can be expected to supersede the older method within a measureable time. This modern process is cleaner, quicker and more economical in fuel, labour and materials than pack carburising, and furthermore, it permits that degree of precise control over the operation which is demanded by modern heat-treatment specifications and which is difficult or impossible to achieve by the older method. Birlec have pioneered the development of equipment on a sound practical basis, and by virtue of extensive experiments in this process, all types of equipment are offered for every carburising application—batch and continuous, electric or fuel fired.

The standard Birlec continuous belt conveyor controlled atmosphere furnace will be exhibited in operation. This unit, which is equipped with atmosphere generator, is already well-known throughout the country where it is used in many industries for bright annealing pressings and other small parts, and for the bright copper brazing of small steel assemblies.

Examples of Birlec high-frequency induction heating equipment will be shown demonstrating particularly the highly-developed mechanical devices built by Birlec for the automatic feeding of the material and timing of the process. The induction heating exhibits will be centred round a small working model of the rotary type continuous billet heating machine which Birlec is building for large production requirements. Twelve full-size units of the same type of model on a production scale are being built for a large forging installation to handle an output of 10 tons of forgings per hour, the induction heating plant being used for heating billets up to 6-in. square for the forging presses.

**G.W.B. Electric Furnaces, Ltd.,** Stand No. 147. The size of furnace normally manufactured by this firm precludes the exhibition of actual production equipment which will, however, be illustrated by photographic enlargements and scale models. In addition, the well-known " Autolec " electrode steam raiser will be shown in operation. Heat-treatment requisites, including Eternite casehardening compound and Shell-Wild-Barfield quenching oil complete the exhibits.

**Wild-Barfield Electric Furnaces, Ltd.,** Stand No. 148, exhibit a range of equipment, the emphasis of which is on toolroom, workshop and small production rather than full-scale production, but laboratory and radio-frequency equipments are represented. Laboratory muffles will include model M94, a twin-tube muffle for temperatures up to 1,050° C., fully self-contained, with built-in energy regulator and pilot lights. Tube dimensions, 20 in. × 2 in. diameter. Also to be shown is a horizontal rectangular muffle, model M254, which is complete with pilot lights, built-in energy regulator type hand temperature controller and contactor and excess temperature cut-out giving a normal maximum operating temperature of the order of 940° C. Chamber dimensions are 19 in. × 7½ in. × 5 in.


**The Birlec continuous rotary induction billet heating unit. (A small model built on the production unit)**

Toolroom and workshop equipment will be represented by the well-known TRT.1010 forced air circulation toolroom tempering furnace, the horizontal " Workshop" furnace with its own Paragen atmosphere control system and the two alternative models of the " E.S.B. Minor " Electrode Salt Baths, one with the refractory pot for high temperature heat-treatments and the other with a metal pot for heat-treatment in the range 550°/950° C.

For hardening high-speed steel, a high-temperature furnace—model HTP4—will be shown for the first time. This equipment follows a well-tried design and incorporates its own Paragen atmosphere control. Heating elements are of the non-metallic variety giving a normal operating range of from 1,100°–1,350° C. Control is effected by a tapped transformer and automatic temperature control panel. The length of chamber is 18 in. with a door opening of 6 in. × 6 in. The equipment is rated at 18 kW.

The use of radio frequency is increasing in a number of industries. Equipment will be shown to cover both dielectric and induction heating. For the former application, the Ferranti-Wild-Barfield pellet heater, model 2BDP will be exhibited. This equipment provides an output of approximately 1 kW of radio frequency energy at a frequency of between 33 and 36 megacycles per second. On the induction side, an entirely new equipment will be on view. This has an output of approximately 1 kW of radio-frequency energy at a frequency of 1 megacycle per second, and may be used for surface hardening, soldering and brazing small articles in the production line. To supplement the dielectric and induction sets, samples of typical work carried out using these methods will be shown.

**Philips Electrical, Ltd.** on Stand No. 257, Empire Hall, are showing a number of their wide range of products which include the latest model of their magnetic clarifier; magnetic filters and skimmers; magnetic drain plugs; and a radio-frequency generator. The latter is model F.5 which was specially designed for use on

Philips magnetic clarifier

Philips radio-frequency generator


**300 ton double-action Clearing press by Vickers Armstrong, Ltd., exhibited by Rockwell Machine Tool Co., Ltd.**

small jobs, mainly for hard and soft soldering work, spot heating and local hardening of small components. It has a rated output of 2·5 kW at the terminals. Features of this instrument are flexibility and easy adaptability to the job. A six-position matching control switch makes it possible to obtain full power over a wide range of applications, and an on-load continuously variable power control brought to a knob and scale on the front panel is also provided, giving smooth control of power from almost zero to maximum. These features make the generator particularly suitable for production work where small batches of jobs of different kinds have to be treated, and for experimental work. Other controls on the front. The power consumption of the F.5 is 5 KVA at 0·5 power factor, and it is suitable for a single phase A.C. mains supply at 200–250 volts. Overall dimensions are 60 in. high, 33 in. wide and 28½ in. deep. The generator is mounted on castors for easy movement.

**Brayshaw Furnaces & Tools, Ltd.** are exhibiting on Stands Nos. 149, 150 and 151. Export will be the keynote of the display and the furnace exhibits, which will cover a wide range of applications, including six working appliances—electric and gas-fired high-speed steel furnaces, electric and gas-fired ovens for general heat-treatment, and a small gas-fired muffle furnace. Other furnace plant on view will be an air circulation furnace for low-temperature heat-treatment, an electric salt bath for high-speed steel, a crucible furnace for melting non-ferrous metals, a salt bath equipped with automatic stirrer and a small pottery muffle furnace. Whilst only gas and electrically-heated furnaces are exhibited, there is an oil-fired alternative design to many of these types. The photographic display will deal mainly with larger furnace plant of Brayshaw manufacture and will contain views of such installations as bogie hearth, automatic, conveyor, forced circulation and salt bath furnaces, as well as special process equipment.

The display of precision small tools includes milling cutters, form ground tools, cutters and hobs, Mikron hobs, interlocking wood cutters, hacksaw cutters, etc. covering an extensive range of types. These products of Brayshaw manufacture further serve to demonstrate the performance of the furnace exhibits, all of the tools exhibited having been treated in similar furnace plant to that on view.

One of this Company's most recent developments is a range of electrically-heated oven furnaces for hardening carbon steels, annealing, normalising and preheating, also for glass annealing and the heat-treatment of non-ferrous metals. This type of furnace, one of which will be seen in operation, has a maximum working temperature of 1,000° C. and includes the latest in design and construction. In the larger furnaces, the inner refractory lining is provided with locked joints, and extra insulation is included. The hearth plate is of silicon carbide or alternatively an alloy steel hearth plate can be provided. The door which is hand-operated, is of the rising and falling type suitably counter-balanced. Alternatively a compressed-air operated door with foot control can be supplied. An automatic switch is included in the door mechanism which cuts off the supply of current to the heating elements when the door is opened. These furnaces can be arranged to suit any voltage, one, two, or three phase alternating current, although a transformer may be necessary in certain cases. They can also be arranged for direct current.

### Miscellaneous Equipment and Materials

**Rockwell Machine Tool Co., Ltd.** are exhibiting, on Stand No. 89, Grand Hall, Vickers-Armstrongs "British Clearing" press brakes and presses. A typical example of British Clearing power presses is an all-welded construction precision double-action power press, type DF.2300–66 which will be on view. Crankshafts

are replaced by eccentrics, and the whole crown assembly is running in an oil bath. The slides are operated by plungers which are guided in the crown and attention is drawn to the exceptionally long guiding gibs of the slide. The machine is fitted with an air-operated friction clutch and flywheel brake. Air-operated cushion equipment with a locking device is shown by the side of the machine.

An entirely new development is the smallest press in the "British Clearing" range, it is an open-back inclinable power press, type N.45, and it is being exhibited. Attention is directed to the extremely long guides of the ram, the single lever control for non-repeat and continuous running and the air-operated friction clutch with which this high-class machine is fitted. Its capacity is 45 tons; length of stroke, 6 in.; bed area, 24 in. × 18 in.; and strokes per minute, 90.

It is noteworthy that a working model, built to scale, of a "British Clearing" triple-action press, type TF.41500–180, which is a true replica of a number of full-size machines of this type manufactured, and now used in the production of motor car bodies. Visitors should note particularly the timed operation of the inner slide and blankholder and the lower crown operating through the bed.

**The Mond Nickel Co., Ltd.** on Stand No. 228F use as the theme of their exhibit the enhanced precision in machine tools achieved by the use of nickel alloys and the services the Company has to offer to engineers and designers. Modern production methods, involving the use of more efficient cutting tools, higher machining speeds and simplified operation, coupled with the modern demand for precision of output, have led to the development of sturdier and more durable designs in machine tools. These conditions could not have been met without the availability of materials of construction capable of handling the higher unit stresses involved and sufficiently wear-resistant to maintain the high accuracy and smoothness of operation required.

Modern materials largely owe their superior qualities to their alloy content. One of the most important of these alloys is nickel, which is clearly indicated by the fact that all leading tool producers employ nickel to greater or less extent in steels and cast irons.

**E. W. Bliss (England) Ltd,** are exhibiting two power presses—No. 675 high-production press and No. 322 body maker. The former is one of a range developed to accommodate a growing demand for press equipment to produce large quantities of stampings requiring comparatively short strokes. These automatic presses are now extensively used by manufacturers of motor-cars, electrical equipment, household utensils, etc. This press, which operates at up to 200 strokes per min., incorporates an automatic double-roll feed with scrap-cutting device. It is fitted with direct V-rope motor drive and driven by a 10-h.p. motor coupled to a "Varatio" gear box.

The No. 322 automatic body-making machine is an all-crank machine for producing round, square and irregular shaped can bodies at a rate of up to 300 per minute. The design and construction are such as to ensure maximum life. All motions are short and actuated by eccentrics, eliminating the wear, noise and limitations as regards speed that are inherent with cams. The driving mechanism runs in an enclosed oil bath. All working parts are open and readily accessible for inspection and adjustment. Soldering attachments with inside or outside solder horns, beading and necking-in attachments, can be supplied when required. These devices are direct connected and function as a unit with the bodymakers.

**Eumuco (England), Ltd.** are exhibiting a British Eumuco 1,500 kg. air hammer, and a British Eumuco 1,000-ton knuckle-joint coining press. The latter, which will be working under power, is designed for coining, embossing and sizing of ferrous and non-ferrous metals, where high unit area pressure must be applied. The press is a totally enclosed electrically-driven unit. The drive is taken up through a multiple disc friction clutch air operated which is positive in action and ensures engagement free of shock and noise. Moving masses are arrested by a multiple disc brake, mounted on the same shaft as the clutch. The stroke is adjustable from a range of $\frac{1}{2}$ in. to 2 in. according to requirements and size. The machine is built in sizes from 250 tons upwards.

**Humphris & Sons, Ltd.** are exhibiting presses which are notable for the comprehensive range of automatic feeds designed for use with them and adaptable for fitment to other makes of presses. A 10-ton overhung crank press will be on view and fitments include a double-roll feed, a gate gripper feed, and a single roll feed.

A $12\frac{1}{2}$-ton multi-toggle press will also be on view, and it is probable that a 20-ton inclinable crank press will also be shown. This latter machine is the newest of the Humphris range, it incorporates features which are the result of 25 years' experience. The generously sized bed—26 in. × 20 in.—is provided with a large rectangular clearance hole, enabling special bolsters to be used on long and awkward pressings.

**Renold & Coventry Chain Co., Ltd.** The exhibits of this Company of precision chain engineers, will comprise a range of transmission chains suitable for machine tool applications for main, secondary and auxiliary drives and motions, together with power transmission accessories—clutches, couplings, counterweight and rack sets. An example of the push-pull remote control system will also be included in the exhibits.

**Lincoln Electric Co., Ltd.** on Stand No. 52 will be departing completely from the normal methods of displaying machine tools, and will be demonstrating the various applications of arc welding by means of a daylight cinema. Films dealing with such subjects as machine design, structural design, arc welding in agriculture, and distortion in arc welding, will be shown throughout the exhibition, and a team of engineers will be in attendance to answer questions resulting from these films.

In addition, standard Lincoln shield-arc welders will be shown, and a revolutionary type of welding machine, details of which will be released at the exhibition. A full range of welding electrodes and accessories will be on display, together with some authoritative data on the subject of the welding of class 1 pressure vessels.

**Carborundum Co., Ltd.** will be featuring their remarkable discovery, known as "MX." This is the name given to what bids fair to be a very considerable advance in the abrasive field. Primarily intended for use on metal in deburring, breaking down sharp edges, polishing dies and moulds and de-flashing and polishing diecastings, the useful sphere of "MX" has now been extended to the plastic, cutlery, optical, radio and scientific instrument trades. Many successes are reported, and it is likely that a practical demonstration will be a feature of the exhibit.

**Taylor, Taylor & Hobson, Ltd.** exhibit on Stand No. 237, Grand Hall gallery, the "Talysurf" surface meter for measuring the texture of surfaces. It provides both a graph showing a cross section of the surface, and a number representing the average height of the texture. A pick-up unit having a sharply pointed stylus is traversed across the surface by means of a motorised driving unit. The up and down movements of the stylus as it rides over the surface are converted into a correspondingly varying electric current, which is amplified and then applied to one or the other of two measuring instruments. One of these instruments is the recorder, which provides a graph drawn on paper, representing the geometrical shape of a cross-section of the surface undulations. The other instrument is the average meter, which gives the number representing the average value of the undulations.

The magnification of the height of the undulations can be varied in steps over a very wide range. The standard self-contained magnifications are from 2,000 to 40,000, but by means of accessories, the range can be extended down to 400 and up to 100,000. In the direction along the length of the surface the magnification is 200 or 50. A feature of the instrument is the ease with which the magnification can be checked by the user, starting from a pair of slip gauges.

**Fisher & Ludlow, Ltd.** The feature of this Company's exhibits is the wide range of industrial efficiency aids. In the fields of steel fabrications, factory equipment and mechanical handling equipment "Fisholow" products have made considerable progress, but visitors to this Exhibition will have the opportunity of appreciating the range of these products. New products, and new adaptation of existing ones, are constantly adding to this range. Research into production and storage and handling problems is constantly in progress.

Many of the products displayed are accessories to machine tools, such as trays, boxes, bins, suds tanks, and solid steel machine guards. In the storage equipment section, an interesting item exhibited is "Flowator," a system constructed of mobile racks, which can be arranged to any pattern convenient to individual requirements. Other examples of "Fisholow" storage equipment include the "Flowrack" system, which speeds up and facilitates handling between given points on a production line; multi-storage equipment of the "Uniflowbin" type; "Uniflow" tables, suitable for light assembly and inspection, and for inspection and packing; various types of Treadway open-steel flooring; and examples of unit-construction in partitioning are only a few from this wide range.

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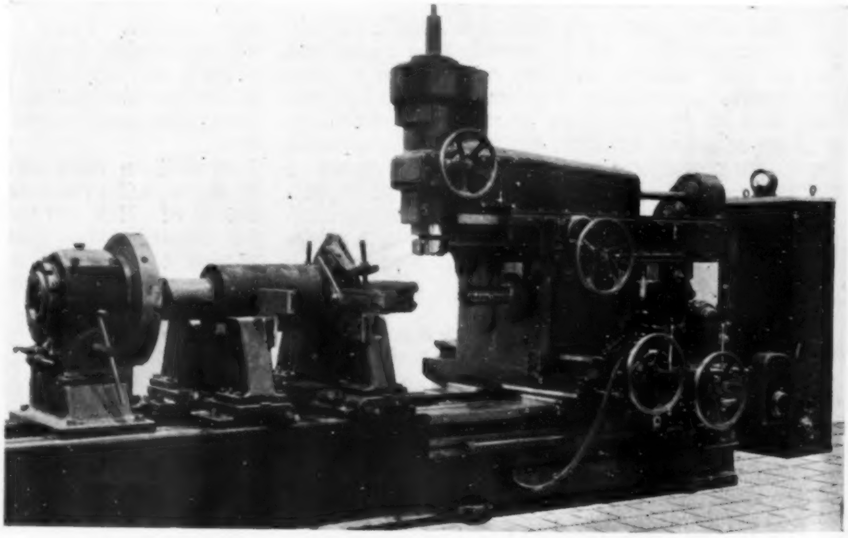
# Craven Bros. Exhibit Large Machine Tools at Reddish

Craven Brothers are not exhibiting at the Machine Tool and Engineering Exhibition at Olympia, but they are making special arrangements to receive visitors from home and abroad in their Vauxhall Works, Reddish, near Stockport, during the period 26th August to 11th September. About fifteen typical "Craven" machine tools will be on demonstration work under power; they will include: lathes up to 55 in. centres; railway wheel lathes; a large vertical boring and turning mill; worm-thread milling and grinding machines; heavy-duty roll turning lathe and wobbler-end milling machine; a universal gear-hobbing machine and several special railway machine tools.

In addition to the above, there will be many other machine tools to be seen in various stages of erection, and visitors will be able to make a comprehensive tour of the "Craven" Workshops and to view the excellent manufacturing plant. A special roll-tenon and wobbler-end milling machine, similar to that which will be exhibited is shown in the accompanying illustration. It will be noted that both horizontal and vertical spindles are incorporated in the design enabling the machining of a large variety of different types of rolling driving ends, keyways, radial holes, etc.



**"Craven" Special Roll Tenon and Wobbler-End Milling Machine.**

# First International Powder Metallurgy Conference

## By a Special Correspondent

***Representatives of about fifteen countries attended this international Conference at Graz, Austria, which proved a great social and technical success. Some indication of the progress of powder metallurgy is shown by the fact that 70 papers were presented at the technical sessions, covering the whole field from powder production to finished products. Many border-line subjects were also discussed as is indicated in this brief report of the Conference.***

THE first international powder metallurgy conference was held in Graz, Austria, between July 12th and 17th, and was very well attended by representatives of at least 15 countries. The organisation was directed by a committee under the chairmanship of Dr. Kieffer, of Reutte, and excellent arrangements were made for the foreign guests during the Conference. Nor was the entertainment of the visitors overlooked and many receptions, concerts, theatre visits, and tours, etc., had been arranged, which were greatly appreciated. The warm hospitality of the people of Graz was very marked, and was instrumental in making the Conference a great success. During the Conference honorary degrees were conferred on Dr. W. D. Jones, of London, Dr. P. Schwarzkopf, of New York and others.

The whole field of powder metallurgy was covered, from powder production to finished articles, but in addition great attention was paid to the borderline subjects which are of considerable theoretical importance in powder metallurgy. Ceramics and metal-ceramic bodies, surface phenomena and reactions, X-ray diffraction and electron microscope methods of investigation, metallic bonding and so on were discussed. Seventy papers were presented, so that it became necessary to divide the papers, and run two series of discussions. On the first day papers included under the heading of general fundamental and borderline subjects were presented in one lecture hall, whilst the subject of hard metals was discussed in the other. The carbide section was the only one in which British papers were presented, and here the healthy state of the industry in Britain was revealed when five of the ten papers were found to be by British authors.

### Solid Reactions

The Conference was opened in the first lecture room with a paper by M. Hausner, of Zurich, on silicon-containing ceramics. He showed that by adding 75% of silicon as a high ferro-silicon the heat conductivity is greatly increased, giving a material very suitable for acid-containing vessels which have to be heated. He discussed the sintering of this type of material, where the water-vapour from the clay and the iron set up an equilibrium by which the porosity may be regulated. The next paper by E. Meyer-Hartwig also dealt with similar materials whose properties varied continuously between those of metals and ceramics. Other papers in this section dealt with solid reactions of various types. Y. Kauko discussed the ionic reactions which take place in slags and their application to the influence of oxide films on the sintering of compacts. A. Smekal gave a paper on the commencement of the reaction between solids. An interesting paper in this section was by Prof. Hedvall who surveyed the present state of knowledge on the influence of surface activity on powder metallurgical processes. The influence of such factors as surface area, surface condition, absorption, valency electron concentration and so on were discussed, particularly with reference to catalysts. A change-point in the metal powder leads to increased activity and examples of this are the increased rate of oxidation of powders near a change point (Ag-Cd at 433° C.), and the increased rate of solid reaction. The magnetic change-point also has considerable effect illustrated by increased catalytic activity (e.g., for the reaction $CO + 3H_2 \rightarrow CH_4 + H_2O$ over cast iron). The effect of super-sonic radiation on a reaction such as that of copper powder with iodine vapour was mentioned. Although all of these phenomena have no direct application to powder metallurgy, this paper emphasised the importance of surfaces in the sintering process, giving some new methods of measuring the quality termed "surface condition," and thus presents some additional means of investigating the sintering process. D. Balarew, of Sofia presented a paper on the "caking" of non-metal powders and metal salts using a rotating platinum probe dipping into the powdered material to enable a curve of temperature against "caking" to be obtained. He extended his results to mixtures also, and comes to the conclusion that an amorphous type of bonding must be formed, and at a critical temperature this leads to a maximum rate. Transformations were found to lead to a minimum rate of caking.

Other papers in this section dealt with contact methods of thermal analysis (L. Kofler), the influence of inert gases on the properties of thin wires and sheets (Torkar), and two papers dealing with metallic bonding (M. Koch and E. Schwarz-Bergkampf).

### Carbides

In the second lecture room the conference was opened with a paper by A. G. Metcalfe (Cambridge), on the preparation and some structural properties of alloys of titanium carbide and tungsten. His paper outlined earlier results* and in addition gave some measurements of the electrical resistance of cemented carbides from which a solubility of tungsten carbide in titanium carbide was botained, agreeing with the X-ray results. The variation of the lattice parameter of titanium carbide and of titanium carbide-tungsten carbide solid

* *Jour. Inst. Metals*, **73**, 1947, 591.

solutions was studied, and it was concluded that when both oxygen and vacant lattice sites are present in the lattice, only the presence of oxygen causes a reduction in the lattice parameter. This suggested a means of detecting oxygen even if the carbide is not saturated with carbon. In the discussion, Professor Nowotny claimed to have found a solubility of 10% titanium carbide in tungsten carbide around 2,500° C., but Brownlee supported the results given in the paper.

The next paper by H. Burden (Sheffield), dealt with the use of heat-tinting to distinguish between the various carbides in cemented carbides containing titanium. Some excellent photomicrographs illustrated this difference and estimations were made of the solubility of the two carbides. The effect of sintering temperature was studied and inhomogeneity noted in the heat-tinting of the titanium containing phase which was thought to be due to variation of composition. The effect of various times of heating on the appearance of the $\eta$-phase was studied, from all of which it was apparent that here was a very useful method of examining these carbides. R. Kieffer (Reutte, Austria) then presented a paper on tungsten-free hard metals. This problem had been approached in two ways : in the first, boron carbide and alumina were used, but poor strength materials were obtained, whilst the second method was to use other carbides, nitrides, or borides, bonded with a suitable metal. In this connection solid solutions of the carbides of the 4th, 5th, and 6th groups of the periodic table were investigated. With the cubic carbides the size factor was most important in determining the extent of the solubility, but alloys of a cubic carbide and a carbide from the 6th periodic group of metals showed a considerable single-phase region for the cubic solid solution, but a very small field for the 6th group metal carbide. The best combinations found were nickel-bonded alloys of titanium carbide with either vanadium carbide or molybdenum carbide, but these have been fully discussed previously. M. Ostwald (Paris) followed with a paper on titanium carbide, in which he discussed the formation of a porous core in titanium grade carbide, due to gas released in sintering. The decomposition of titanium nitride and oxide was also discussed, and it was suggested that a solid reaction took place with tungsten carbide to form a transitional tungsten nitride or oxide, respectively. He also suggested that a super-lattice was formed at the composition $T_3$ $WC_4$. L. D. Brownlee (Manchester), dealt with the ternary system W—C—Co, which he had investigated mainly at 1,350° C. using the X-ray diffraction technique. He showed that the double carbide ($\eta$) had a large single-phase region and did not decompose to the $\eta_1$ and $\eta_2$ phases reported by Kislyakova at this temperature, but did so towards 1,000° C. Also it was not meta-stable as reported by Tokeda. Two new features were reported. The first was that tungsten carbide can take up 5% of cobalt after long times of annealing, although rapid quenching is necessary to retain it, and the other new result was the suggestion that $W_2C$ is unstable at this temperature. The evidence for this was admitted to be poor, and was that $W_2C$ tends to decompose to WC + W on prolonged annealing in vacuum, whilst it has so far proved impossible to prepare $W_2C$ without WC or W.

There were three papers on the examination of carbides. H. Krainer (Kappenburg, Austria) discussed physical methods of examining carbides, and stated that X-ray diffraction techniques could be used to estimate the amount of carbon in tungsten carbide giving a method which compared favourably with classical methods for cost and speed. Both X-ray and magnetic methods were available for detecting the presence of $\eta$-phase (double carbide). In titanium carbide the combined carbon could also be estimated, since the lattice parameter of the carbide decreased with the carbon content. This conclusion is in contradiction to that found by Metcalfe who claimed that only oxygen decreases the lattice parameter and not vacant lattice sites. A paper by F. Skaupy (Berlin), on methods of investigating carbides was only read in the summary owing to the absence of the author. The third paper on physical examination was by D. H. Shute (Bedford, England), on an X-ray method of measuring and controlling grain size in hard-metal powders, where a novel type of microphotometer had been developed for the purpose.

The paper by A. E. Oliver (Coventry, England), read by E. H. Trent, was of a more practical nature and dealt with the causes of defects in sintered carbides. These were divided into six groups : holes and inclusions, cracks, dimensional inaccuracy, chemical composition, metallographic or structural defects, and miscellaneous. An important conclusion with regard to holes was that generally they are either very large or very small (less than 0·01 mm.), and it is only the large holes which are very serious. These holes were considered to be generally due to impurities, which either volatilise or fall out in polishing (e.g., in a drawing die). Some interesting results were given for the contraction from which it appeared that the cutting of components from larger pressed blocks required considerable experience and knowledge of the way in which the block had been pressed. Defects in structure such as over or under sintering, decarburisation, and oxide in the powder, were well illustrated by photomicrographs. The last paper in this section was by S. J. Sindeband (U.S.A.), on cemented chromium borides. Chromium boride was shown to be single phased in the range 12–20% $B$ with a defect lattice centred around Cr $B$. Hot-pressing with and without a bond of 15% Ni, Ni-Cu, Ni-Cr, and Co, was carried out, and the best strength obtained in a transverse rupture test was 120,000 lb./sq. in. with 15% Ni which had a hardness of 89 Rockwell A. For a 30% Ni alloy creep tests indicated strengths about a quarter that of vitallium, whilst the formation of liquid nickel borates in air at over 1,000° C. limit the use of the material.

## Surface Reactions

Two more papers on surface reactions were presented ; by E. Fitzer (Vienna), on the formation of columnar crystals and super-saturated regions on the diffusion into metals with a change-point, and by M. Niessner (Vienna) on the carburisation of tungsten and molybdenum-coated steel. Fitzer showed that above the $A_3$ point a super-saturated $\gamma$ solution is formed which transforms to $\alpha + \gamma$ with the formation of columnar crystals. Rapid cooling to below the $A_3$ leads to shorter crystals. Niessner used Halla's method of coating steel by treatment in molten sodium tungstate or molybdate, and obtained hardness increases around 100% by gas carburisation. The reaction mechanism involves formation of $Fe_3C$ with diffusion of tungsten inwards. The temperature of carburisation is important since this determines the initial structure of the alloy, and a temperature such that the structure is $\alpha + \gamma$ gives the

maximum hardness with the formation of double carbides.

### Magnetic Properties

L. Weil and L. Néel (Grenoble) presented papers on the properties of very finely divided ferromagnetic materials and on the theory of the influence of porosity on the coercive force and saturation of ferromagnetics. Both papers dealt with the subject in a theoretical manner, although Weil gave some interesting results for the properties of pressed compacts composed of very fine powder, showing the influence of compacting pressure. The variation of the coercive force with temperature for different porosity ranges in iron, cobalt, and nickel powders was illustrated. The importance of grain size and surface condition for optimum properties was illustrated by cobalt powder photographed with the electron microscope. R. Steinitz (U.S.A.) investigated the variation of permeability of four iron powders sintered at 1,150° C. and found that the permeability varied with the density, but there was very little difference between the powders. At 1,250° C. this was not so, and it was suggested that the different powders have different surface activities leading to different rates at which the pores became spheroidal. H. Rainer (Graz) discussed the effect of surface condition on the magnetisation curve, and by means of special apparatus gave the powder such different treatments as acid etching, colouring with organic dye, acid and alkali etching in $CO_2$, heating in air at 200° C. and rusting followed by a low temperature hydrogen reduction. Carbonyl iron powder maintained better properties throughout (with one small exception) than electrolytic powder.

### Properties of Powders

In the section on the investigation of sintered and unsintered powders was a paper by M. Bernard (Lyons) who showed some interesting electron microscope photographs of powders. Other papers described X-ray method for powders, particularly at high temperatures, and micro-chemical methods of analysis. G. Naeser (Duisberg) described a new method of determining oxygen in iron powder, steel and other metals involving the heating of the powder in a carbon crucible to 1,300° C. and measuring the carbon monoxide evolved. Accuracies of 2—3% falling to 10% below 0·3% $O_2$ were claimed. Some results were given showing the progress of the reduction of oxides of molybdenum, tungsten, manganese, and vandium at 1,320° C. and 1,500° C. H. Grubitsch (Graz) reviewed the subject of corrosion in powder metallurgy and showed that special effects result from the pressing of the powders. Subsequent heating causes considerable changes to take place in the rate of corrosion of compacts. Copper, tin and iron compacts were investigated and polarisation curves were plotted. The prevention of corrosion by the usual treatments (phosphating, etc.), is possible.

### Sintered Products

The first paper in the section on the production, properties and use of sintered bodies was by J. D. Fast (Eindhoven) on the high melting point metals which are difficult to produce by conventional methods. In his paper he described the iodide method for preparing Ti, Zr, and V, particularly in the ductile condition, and the newer American developments for vacuum-melting molybdenum and the production of Ti and Zr by reduction of the tetrachloride with magnesium. R. Kieffer and F. Benesovsky (Reutte) described their investigations on the production of manganese and chromium-manganese steels from Hemetag iron powder, ferromanganese and electrolytic chromium. New and interesting properties were obtained by liquid copper impregnation after sintering, having good hardness with very low porosity. Heat-treatment was carried out and the structures obtained were illustrated by photographs. Four American papers were then presented, but owing to the absence of the American investigators, the discussion was not as profitable as it would otherwise have been. Papers on high strength ferrous parts by powder metallurgy by G. Stern, on developments in moulding metal parts by R. P. Seelig, on ferrous structural parts by F. V. Lenel, and on finished parts by A. Langhammer were presented, and discussed. Standard parts in steel, iron and copper, and steel and copper are made in U.S.A. in runs of 50,000 or more, where strengths of 25 tons /sq. in. may be obtained. A discussion on tool costs resulted from the statement in Langhammer's paper that in favourable cases the tool cost may be only 5% of the total cost, and Dr. Kieffer said that in his experience a range of 10—60% would be regarded as representative. It was also stated that for the same part, in general the cost was higher than by precision casting, but lower than for die-casting.

### Light Metals

In the afternoon R. Muller and collaborators (Graz) presented a paper on sintered compacts of iron and light metals. Alloys of iron and magnesium, iron-calcium, and iron-calcium-aluminium were made by sintering. These possessed good hardness but they were found to be exceptionally good in resistance to corrosion over a period of testing lasting four years. On the other hand, iron-zinc alloys were found to be poor in their corrosion resistance. R. H. Hausner (New York) presented a paper on the electrical properties of sintered materials, and from a study of the electrical resistance of metal and non-metal combinations was able to investigate the sintering, since the resistance depended on both the resistance of the particles and the contact resistance. E. Nachtigall (Reutte) reviewed the earlier work on the powder metallurgy of light metals, and came to the conclusion that many useful materials could be made from compositions removed from those used in alloys made by conventional methods, and also from combinations of aluminium and non-metals. The use of aluminium-graphite for sliding contacts and of aluminium-hardmetal materials for grinding was mentioned. Alloys with 4—50% Fe ; 2—20% Mn ; 13·5—30% Si and 10—95% Cu were investigated, and slides were shown illustrating the structures obtained.

### Hardness Testing

H. Bückle (Paris) gave some interesting results on micro-hardness determinations using the Hanemann method of hardness testing. Pure metals such as W, Mo, Nb, Ta and binary alloys of these metals were investigated, as well as carbides. Kieffer had earlier expressed the view that micro-hardness measurements were a very useful tool for the examination of carbides, because it was then possible to investigate both the bond and the carbide separately. It also enables the effect of porosity to be reduced. Bückle used Kieffer's

technique of prolonged sintering to obtain larger grained materials, so that his results were not directly applicable to normal sintered material. E. M. Onitsch (Leoben), applied Meyer's analysis to the problem of sintered materials in order to follow the degree of working in pressed and sintered compacts. The values are load-dependent so that curves for various loads had to be compared.

### Theory of Sintering

The theory of the process of sintering was discussed on the last day. P. Schwarzkopf (Yonkers, U.S.A.) read a paper on the subject in which he advanced explanations similar to the surface energy relations used by Prof. C. S. Smith to explain the occurrence of various structures in alloys. On the other hand W. E. Kingston (New York, U.S.A.) thought that the formation of bonds took place by a recrystallisation starting from the distorted metal at the points of contact between grains, with subsequent grain growth. The importance of a good technique in preparing specimens so that the weaker bonds between grains were not broken was stressed, and a series of photomicrographs of iron compacts were given to illustrate the suggested theory. Undoubtedly the most complete investigation of sintering was by G. F. Hüttig (Graz), who considered the fine processes of thermal vibrations inside and at the surface of a crystal, self-diffusion inside and on the surface of a crystal, and melting. Phase changes, impurities, mosaic structures and activated states are considered to be deviations from the ideal conditions, where a pure, single-phased metal is used as the model. For such a metal the temperature may be expressed as the fraction of the melting point: thus at $a=0 \cdot 23$ (that is $0 \cdot 23\times$ absolute melting point) self diffusion on the surface of a crystal becomes evident. It is pointed out that the forces causing sintering are weakened with rising temperature, although the rate of sintering is increased, and a temperature in excess of $0 \cdot 23$ times the melting point is required before bonding takes place (adhesion due to thermal vibration exists as a result of pressing). A temperature factor of $0 \cdot 33$ must be reached before self-diffusion takes place inside the crystal, and then stress-relief and recrystallisation can begin. In the case of the fritting of powder mixtures to form a compound, the stages suggested are reduction of surface area, activition of surface atoms, formation of compounds, and subsequent crystallisation.

P. Duwez (Pasadena, U.S.A.) presented some interesting dilatometer results on the sintering of alloys of copper with nickel, zinc, and tin. He found that up to a definite temperature the expansions recorded were those of the solid metal, unless the pressure used was over about 27 tons /sq. in. when larger expansions were recorded. These might be due to the release of gas from the compact. Copper-zinc compacts exhibited unusual expansion in the range of 300—550° F. and unusual shrinkage above 1,100° F., and it was suggested that diffusion of zinc into copper causes the copper grains to increase in volume leaving voids where the zinc particles were initially. These voids are responsible for the rapid contraction above 1,100° F. The low solubility of copper in zinc is suggested as the reason for the formation of only a copper-zinc solid solution. Copper-tin compacts gave similar results, but the effect was reduced. This was thought to be due to the compositions which were 30% Zn, but only 10% tin.

Dawihl and Rix (Saarbrücken) had studied the shrinkage of compacts, and were mainly interested in the way in which the pores become filled. Increasing fineness of powders, and increasing internal and external stability are accompanied by an increase in the rate of shrinkage, and an increasing ease of pore-filling. F. Kahler (Radenthein) studied the sintering of magnesia by means of the electron-microscope, particularly in cements, and observed recrystallisation and sintering.

### Powder Production

The last section dealt with the production of powders, and here an interesting paper was given by E. Pelzel (Linz), who described the production of powders by reduction of solutions of metal salts by a less noble metal. An example is :—

$2Cu_2\ Al+3\ CuSO_4 \rightarrow Al_2\ (SO_4)_3+7\ Cu.$

The copper-alloy had to be milled to less than 60 microns (under 200 mesh) in order to obtain complete replacement of aluminium by copper. With large sizes copper layers form on the outside impeding the reaction, and it was suggested that such grains would be very suitable for producing powders to make aluminium bronzes. Brasses could also be prepared by this method. R. Müller and H. Krainer (Graz) also discussed alloy powders, in this case made electrolytically. Two anodes are used consisting of the two constituents of the alloy, and electrolysis is carried out in a complex iron bath in order to obtain the proper composition by alteration of the decomposition potential in the usual way. A sulphate bath is used for Cu-Cd alloys and a borofluoride for Cu-Pb alloys. Considerable difficulties have been experienced with control of the process owing to depolarisation, precipitation and so on. Current density is important and in the case of Cu-Pb alloys, a variation of the cathode current density from $0 \cdot 25$ to 1 amp /sq. cm., changes the copper content from 97 to 4%.

F. Rapatz and F. Schmidt reported the results of their experience with the D.P.G. process for making steel and non-ferrous metal powders. They find that the oxygen content is usually about 2—3% irrespective of the carbon, and by making a powder with 1–3% C, the oxygen can be reduced to $0 \cdot 2$% by subsequent annealing. Size distributions are usually mainly in the range 60–150 microns (approx. 100–200 mesh,) and appear to be almost independent of the carbon content. Powders with less than $0 \cdot 03$% sulphur and phosphorus can be obtained by melting the original metal in a basic arc furnace. G. Naeser (Duisberg) gave details of the RZ powder produced by atomising, and discussed the effects of metal temperature, nozzle aperture, air pressure, and so on.

F. Skaupy (Berlin) reported some work on the use of the vibration type of mill, from which the conclusions were drawn that the size of the mill does not affect the rate of milling but that the mill liquid was important in determining the rate of milling. Of nine fluids tested n-decylalcohol and isoamylalcohol were most effective, giving milling rates over ten times those found for water.

The papers presented at this Conference, together with the full discussion will be printed later, and should be published in the Autumn. It is intended to print the papers in their original language, but all papers will have translations of a summary into either English or German, depending on the language of the original paper. It is to be published by the Austrian Chemical Society.

## Mr. W. Edgar Hale Honoured

Mr. W. Edgar Hale, founder and chairman of Hale & Hale (Tipton), Ltd., was presented with his portrait in oil colours by his fellow-directors at a private dinner on July 29th. In addition to Mr. Hale, the directors present at the function included, Mr. R. C. Leppington, managing-director, Mr. W. Clarkson, Mr. L. Brain, Mr. F. Coe, Mr. H. J. Turner and Mr. G. A. Wylde.

Mr. Hale and his late brother formed the Company at Walsall 37 years ago. At that time the staff consisted of three men and the work was carried out in what had been a stable. The growth of the Company is indicated by the fact that today it controls one of the two largest malleable iron foundries in Britain, with a pay-roll exceeding 1,0C0.

The managing-director, Mr. R. C. Leppington, presented the portrait with a short but appropriate speech in which he eulogised the persistent work of the chairman in building up the Company to its present stature. In accepting the painting, Mr. Hale spoke of the highly-competitive years during which the Company was established—years when supply exceeded demand. They were strenuous years and it is doubtful whether any area in Britain had harder times than the old Black Country. The iron trade, which had made the Black Country and South Staffordshire known throughout the world, was in the throes of a depression when Mr. Hale first knew Tipton, in 1919. Trade became less and less and a great degree of poverty spread over the district. Since then he had seen the area improve tremendously indeed, today he was inclined to the view that it may be the most prosperous in the country with respect to earnings per head of the population. Possibly some of the credit for the change is due to firms like this Company which have brought new industries to the area, to which the people of the Black Country have freely adapted themselves, and prosperity has been regained.

Mr. Hale, continuing, thought the years had taken toll of him, both physically and mentally, but he had the knowledge and satisfaction that those conducting this tremendously interesting enterprise, which is of considerable national importance, are exceedingly capable. Despite ill-health in the past, it was encouraging to learn that he now felt better than for many years, and he was continuing his duties as chairman of the Company in which capacity he hoped to serve for many years.

## Aluminium Limited Report Progress

Plans for a large-scale bauxite mining operation in French West Africa, involving initial capital expenditures of the equivalent of $6,500,000 are announced by Aluminium Limited in a mid-year statement giving operational results and earnings for the first half of 1948. This Company's estimated consolidated profit for the first six months of the year is $13,250,000, equivalent to $3·56 per share, as against $8,700,000 or $2·34 per share in the first half of 1947, last year's figure was after providing a reserve of $1,000,000 against loss on pre-war investments abroad. Consolidated sales in the first half of 1948 were estimated at $98,000,000, against $68,000,000 in the corresponding period of 1947. Candian and foreign income tax provisions in 1948 were $8,700,000, compared with $7,000,000 provided in the first half of 1947.

Commenting on the first half-year results, the Company states that an increasingly strong demand for aluminium in the first half-year has resulted in expansion of production, particularly by the Company's Canadian subsidiary, Aluminium Company of Canada, Ltd., and in higher net earnings as compared with the same period last year. In common with all branches of industry, Aluminium Limited is encountering the problem of inflated costs of plant replacement and of expansion of existing facilities. Because of these high costs, our plant expansion programme is placing increasingly heavy demands on the earnings of the business.

Engineering and construction staffs will leave Canada in the next few months to commence work on the construction of a bauxite crushing and drying plant, anchorage and shiploading facilities in the Los Islands, adjacent to the French Guinea mainland, some 500 miles south-east of Dakar. Development of the bauxite deposits on these islands is planned to produce 250,000 tons of bauxite per annum for the Company's Canadian aluminium smelters at Arvida, Quebec, thus supplementing bauxite supplies from British Guiana in South America. Production of aluminium ingot at Canadian smelters was at a total of 166,000 metric tons in the first six months of 1948, as against 127,000 metric tons in the first half of 1947. Exports to the United Kingdom have continued at important levels, while shipments to the United States were at the highest levels reached since the end of the war.

## Workers' Annual "Beano" by Air

The workers at the factory of Wolf Electric Tools enjoyed their annual 'beano' in a new manner this year. They pooled their savings to go by air and on Saturday morning, July 10th, they left Northolt in a number of 'planes for Bournemouth, where they enjoyed a full day by the sea until 9-30 p.m. when they flew back to London. The management afforded the workers their full assistance in making this unique 'waysgoose' a success and other works' social clubs, anxious to follow suit, may have full information on the experience and organisation.

Capt. (E.) M. Luby, R.N., retired from the Royal Navy, with effect from 6th July, 1948. During the past two years he has held the post of Director of Engine Research and Development in the Ministry of Supply. He will continue to occupy this post as a civilian.

The British Aluminium Co's Manchester Branch Office (North Western Area) has been removed from Chancery Chambers, 55, Brown Street, Manchester, 2, to 46, Fountain Street, Manchester, 2. The telephone number remains the same: Deansgate 3639. Telegrams: "Britalumin, Manchester."

# Obituary

## Mr. Harry Brearley

With the passing of Harry Brearley, the metallurgical world loses one of its richest characters and the craftsman one of his staunchest admirers. Self-described as "the man who invented knives that won't cut," he will be remembered mainly for his discovery of the cutlery type of stainless steel shortly before the first world war.

Harry Brearley was born the son of a Sheffield steelmaker, in humble circumstances, at the beginning of 1871. After a short period in a clog factory he commenced his association with the steel industry at the age of twelve, his first job being that of cellar boy at the works of Thos. Firth and Sons, Ltd. This occupation was terminated when it was discovered that he was below the age specified by the Factory Act, but he soon returned to the same firm as a bottle washer in the chemical laboratory. This began his connection with the technical side of steelmaking and his progress was due in no small part to the influence of Mr. James Taylor, the chief chemist, who encouraged him in his study of metallurgy.

In 1901, Mr. Brearley left Firth's in order to start a new laboratory at the works of Kayser Ellison and Co., Ltd., and whilst there he collaborated with the late Mr. Fred Ibbotson in writing "The Analysis of Steelworks Materials" which became a standard work on the subject. Returning to Firth's in 1903 he became the chief chemist and later works manager of their Salamander Works in Riga. When Thos Firth and Sons, Ltd., and John Brown and Co., Ltd., joined forces to found the Brown-Firth Research Laboratories in 1908, Mr. Brearley was appointed Director. It was during this period that extensive research on erosion-resisting steels, for the manufacture of rifle and gun barrels, resulted in the discovery of the 13% chromium stainless steel, and the first stainless knives were made for him in June, 1914, by Mr. E. Stuart, of R. F. Mosley, Ltd. Following a well-known and unfortunate controversy on the subject of stainless steel, Mr. Brearley resigned his position as Director of the Brown-Firth Laboratories in 1915, and became works manager and later technical director of Brown Bayley's Steelworks, Ltd., with which company he was intimately associated until his death. In 1932, he prepared a detailed statement of his many researches on stainless steel and its early development. That statement was entrusted to the care of the Cutlers' Company with instructions that it must remain secret until the Forfeit Feast Day of the Cutlers' Company in 1960.

A man of unorthodox training, his original views permeate much of his later writing. In 1933 he wrote "Steelmakers," in 1941 his autobiography, "Knotted String," closely followed by "Earning a Living," and his last book, published by the American Society of Metals in 1946 was called "Talks on Steelmaking"—all of them admirably written and providing much food for thought. In addition he was author of "The Casehardening of Steel," "The Heat-treatment of Tool Steel," "Files and Filing," and "Ingots and Ingot Moulds," the last named in conjunction with his brother Arthur, with whom he was closely associated all his life.

A member of the Institute of Metals since 1919, and of the Iron and Steel Institute since 1905, he was a Past Vice-President of the latter and in 1920 received, at the hands of the late Dr. J. E. Stead, F.R.S., the Bessemer Gold Medal, "the only distinction," he said, "that I have ever coveted." In 1939 he was made a Freeman of the City of Sheffield, an honour he greatly appreciated.

His interest in his fellow-men found expression in the Freshwater Trust Foundation which he founded to make life more livable for those whose occupations obliged them and their families to live in unlovely industrial areas.

## Sir Clifford Paterson

Sir Clifford Paterson, whose death at the age of 68 occurred at Hatford Peace Memorial Hospital on July 26, was one of Britain's foremost authorities on many sections of the electrical industry. He had only recently returned from Australia, which he had visited as a contact between scientific bodies of Britain and Australia, and the announcement of his death would be a blow, not only to Lady Paterson, but to his many friends at home and abroad.

Educated at Mill Hill School, he served a four-years engineering shop apprenticeship and subsequently attended Finsbury Technical College and Faraday House. The first part of his career, from 1901 to 1918, was at the National Physical Laboratory as principal assistant under Sir Richard Glazebrook, responsible for Electrotechnical and Photometric Departments. In 1919 he joined the General Electric Co., Ltd. to establish and direct the G.E.C. Research Laboratories. Under his guidance, these Laboratories, which began with a staff of 29, have developed into the largest of their kind in the country with a present staff of 1,750. He was appointed to the Board of the G.E.C. in 1941 and received his knighthood in the Birthday Honours List of 1946.

Sir Clifford was Past President of the Institution of Electrical Engineers, of the Institute of Physics, of the Illuminating Engineering Society and of other scientific bodies. He was Chairman of the Council of the British Standards Institution and a member of the Advisory Committee of the Department of Scientific and Industrial Research. He served as a member of the Executive Committee of the National Physical Laboratory, and as Vice-President of the Royal Institution and of the Society of Arts. He received the D.Sc. (Honoris Causa) from Birmingham University in 1937 and he was for two years Master of the Worshipful Company of Tallow Chandlers. The last of many honours which he received during his life was the award of the Gold Medal of the Illuminating Engineering Society (America) which was presented to Lady Paterson on Thursday, 22nd July, by Preston Miller, Past President of the Society.

## Stellite Service

Stellite is used in such a diversity of applications and by such a large number of firms that the manufacturers have decided to publish, at intervals, a little booklet giving the latest information on the material and its methods of use. In the first issue of "Stellite Service," details are given of a number of applications and a short article on "Machining of Nickel Base Alloys with Stellite 100" is included. Copies may be obtained from Deloro Stellite, Ltd., Highlands Road, Shirley, Birmingham.

# Conference on Scientific Information

## Recommendations and Suggestions

*Convened by the Royal Society, a Conference was recently held to discuss the possibility of improving existing methods of collecting, indexing, and distributing scientific literature from the point of view of use and service to the scientific community. Many useful suggestions were made in the discussions. The difficulties experienced by research workers in keeping abreast of scientific progress are very real, and the Conference made some recommendations which, if put into operation, should assist in alleviating them.*

THE Royal Society Empire Scientific Conference of 1946 invited the Royal Society, at an early date to convene a conference of libraries, societies and institutions responsible for publishing, abstracting and information services, in order to examine the possibility of improvement in existing methods of collection, indexing and distribution of scientific literature, and for the extension of existing abstracting services. Accordingly, a Conference, convened by the Royal Society, met during the period June 21 to July 2, 1948, to discuss this subject from the points of view of use and service.

The first of the detailed recommendations agreed upon by this Conference, at its closing session, begins with these words: " Editors, referees, and those handling papers in draft form, including the heads of Departments in the Universities and Technical Colleges and the Directors of Government Laboratories, Research Associations and industrial laboratories, might be urged . . . to ensure . . . " and continues with a number of sub-paragraphs of which the first is the oft-repeated plea that manuscripts should be written in clear and concise English.

Many of the recommendations, if they are carried out, will have no small effect upon those preparing contributions to their learned societies and kindred associations; and, in milder but significant degree, upon the difficulties experienced by all workers in keeping abreast of scientific progress recorded in so many papers in each special field. There are also valuable pointers to be observed by those who find onerous the task of setting down their day to day technical findings—not excepting examination candidates.

Those attending the Conference were, primarily, delegates from scientific societies—including, of course, the Institute of Metals and the Iron and Steel Institute—and from bodies such as the Association of Special Libraries and Information Bureaux and the British Standards Institution; the Dominions, India, and the Colonies were represented, and also the U.S.A. Representatives of interested, but non-participating, organisations attended the full sessions, held at the Royal Institution. Sixteen working parties, of delegates, were formed and these met in committee rooms at Burlington House to thrash out conclusions and recommendations under four principal sections of the main subject. These sections were:

1. Publication and distribution of papers reporting original work.
2. Abstracting services.
3. Indexing and other library services.
4. Reviews, annual reports, etc.

At the head of Section 1 was Professor Bernal, whose paper suggesting a kind of clearing-house for the more effective handling of scientific contributions had been heavily criticised in the daily Press. Whether or not the public discussion of the matter, while it was being privately considered in committee, was strictly in order, and to what extent the effect was salutary, are no longer very important. It is more to the point that the proposal, as a distinct, complete idea, was not pressed in plenary sessions (at which the whole Conference debated draft and final recommendations), and that a tribute from one of the Conference Chairmen to Professor Bernal's single-minded, scientific attitude to the work of his section was warmly supported.

Sections 2 and 3 dealt with matters of technical interest to those specially trained in abstracting and librarianship, and of considerable but indirect importance to the authors who use their services. The statement that authors' summaries of their own papers are generally unsuitable for use as abstracts is less surprising than at first appears. Abstracts, as such, are meant to inform a wide field, and the abstractor who overlooks the significance of some supporting argument or fact is gravely at fault in the eyes of some specially interested reader: authors are usually concerned to marshall their main conclusions for the benefit of a particular audience. There is, however, room for improvement in summaries, which are not always well ordered or nicely balanced. Section 3 asks that post-graduates be instructed in how to seek and ask for scientific information. Section 4 contents itself with emphasising the importance of reviews and annual reports in general, and giving a broad indication of the relative importance attached to different kinds of reviews and review lectures.

Returning then to Section 1, the request for clearer writing is backed by the opinion that " authors should be trained in the better preparation of material . . . so as to reduce corrections by printers and authors to a minimum." The recognition that printed words are matters of men and material, not merely of the pen, has not come too early. Welcome as it is, however, a further step should surely have been taken. Neither in the conclusions and recommendations of the working parties, nor in the final recommendations of the Conference, is the problem seriously tackled of how this training is to be done. It is a vital matter, because the accuracy, completeness and order of the original document determines the time, labour and cost of producing the finished publication. Yet, in plenary session, there was only one voice to suggest that this question of training appeared at too late a stage. The speaker remarked that the syllabuses of science courses

are already too full. Nobody disputed the statement—possibly because it has been made so often before—and nobody thought to mention the innovation, by Professor R. O. Kapp, of a course in 'The Presentation of Technical Information,' and the appointment of a lecturer in the subject, at University College, London.

A recommendation much easier to put into practice is that those responsible for appointments, awards and promotions should not judge candidates by the lengths of their writings in learned societies' periodicals. It is extremely unlikely that scientists would be misled by mere length, but adjudicating boards are not always composed wholly of scientists. The *Times*, in a 'fourth leader,' recently referred to someone who knew his subject 'well enough to write a book about it'—an attitude of mind not absent from those whose administrative ability consists mainly of snap decisions based on superficial evidence. An incidental point on length may be interjected here: namely, that it is often unnecessary to publish a table of data as well as a curve based on it; one or the other is usually sufficient, especially if the curve shows plotted points.

The question of whether good service would be rendered by the publication of précis journals had a tepid reception: most people seemed to think they had enough to read already. As a matter of fact, it is not quite so easily dismissed, because a précis journal might at once decide for a particular worker whether or not to read a certain paper in full, and also contribute a substantial record of ascertainable information. The proposal stands as a matter for consideration only.

There was a useful discussion on the method of issuing 'separates'—otherwise known, loosely, as 'pre-prints' and 'off-prints'—copies of a paper made available at, or a little before, the meeting at which it is read. Because societies have to work to programmes there may be a gap of months between the completion of a paper and its presentation; meanwhile, other workers await information that the author would be only too pleased for them to have. The procedure adopted by the Institution of Electrical Engineers was mentioned. Briefly, the 'separates' are issued as soon as the paper has been accepted by the Institution and cleared by the author—though subject to final correction—but those receiving these advance copies are under a 'gentleman's agreement' to ask for a final copy in due course, and to file that version, in place of the earlier one, for future use. Similar practice, it was noted, has for some time been followed by the Institution of Mining and Metallurgy.

The Conference ended, as it began, in full session, under the Chairmanship of Sir Robert Robinson, President of the Royal Society; its recommendations are now for the Council of the Society to adopt or reject as they think fit. If only half are adopted the programme of work will be a heavy one, for which funds will be needed. There is no reason to suppose that these must come entirely from this country, nor indeed is it desirable that any one nation or group should shoulder all the responsibility for the better communication of international knowledge.

## Inauguration of Newton Victor Limited

A New company came into being on July 31st, amalgamating the activities of Victor X-Ray Corporation, Ltd., Newton & Wright, Ltd., and the X-ray research and manufacturing interests of the Metropolitan-Vickers Electrical Company, Ltd., under the ægis of the Associated Electrical Industries, Ltd. As a single, wholly British enterprise, devoted to the design, production, distribution and servicing of x-ray equipment for all industrial purposes, this new company will continue and expand the facilities hitherto provided by its constituent members to users and prospective users of such apparatus.

Victor X-Ray Corporation, Ltd., as a direct branch of General Electric X-Ray Corporation of America, has introduced to British users an increasingly wide range of equipment for standard and specialised industrial procedures. The new company will, of course, retain liaison with its U.S. associates and with the research activities of the famous GE laboratories at Schenectady.

The Metropolitan-Vickers organisation has developed extensively its x-ray design and production activities, particularly in the fields of crystallography and high-voltage apparatus, using x-ray tubes of the demountable and continuously-evacuated type. The first million-volt unit to be designed and installed in Britain was an outstanding Metrovick achievement. Newton & Wright, Ltd., which has been active in the design and manufacture of x-ray apparatus literally since the pioneering days of Röntgen's discovery, has for the last few years been closely associated with Metropolitan-Vickers.

The merging of these three organisations in Newton Victor, Limited, is of particular significance at the present time when the widening scope and increasing importance of x-ray application in the field of metallurgy and of industry in general—coupled with the urgent need for development of export business—is making greater demands than ever upon the industry. Such demands will only be met by higher production and distributive efficiencies and improved standards of service.

Head Offices of Newton Victor, Limited are at 15, Cavendish Place, London, W.1., with Branch offices and service establishments at Belfast, Birmingham, Bristol, Cambridge, Cardiff, Dublin, Exeter, Glasgow, Leeds, Liverpool, Manchester, Newcastle-on-Tyne, Nottingham, Oxford, Sheffield, Southampton.

## Heat Treatment of Aluminium Alloys

Much of the aluminium alloy used in engineering is heat-treated by the suppliers, but occasions arise when manufacturing methods necessitate heat-treatment by the user. For those who are not acquainted with the heat-treatment of aluminium alloys, an understanding of basic principles is necessary if difficulties are not to be encountered. In an attractive 53-page "Noral" booklet, "Heat-Treatment of Aluminium Alloys," an attempt is made to satisfy this need. After considering the theory underlying the various treatments, the book goes on to deal with the practical aspects of equipment and technique. Difficulties likely to arise are discussed and emphasis is placed on the need for adequate temperature control. Particulars of the classification of the "Noral" alloys, and of the heat-treatment temperatures and times, are set out in a number of Appendices. Copies may be obtained from the Northern Aluminium Co., Ltd., Banbury.

# Estimation of Molybdenum in Iron and Steel

## A Rapid Method Using a Simple Photometer

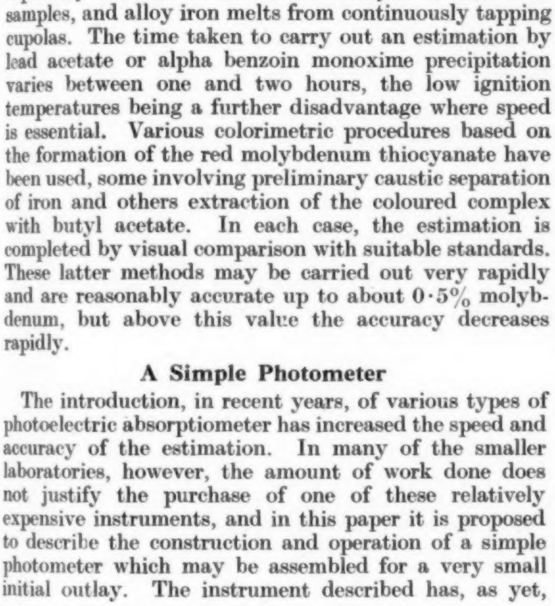
By E. J. Ronnie

*In many small laboratories the volume of work does not justify the purchase of an expensive photoelectric absorptiometer. In this article the author describes the construction and use of a relatively simple photometer for the rapid determination of molybdenum.*

FOR many years there existed a decided need for a rapid and reliable method for the estimation of molybdenum in ferrous materials. This was especially the case in the control analysis of steel bath samples, and alloy iron melts from continuously tapping cupolas. The time taken to carry out an estimation by lead acetate or alpha benzoin monoxime precipitation varies between one and two hours, the low ignition temperatures being a further disadvantage where speed is essential. Various colorimetric procedures based on the formation of the red molybdenum thiocyanate have been used, some involving preliminary caustic separation of iron and others extraction of the coloured complex with butyl acetate. In each case, the estimation is completed by visual comparison with suitable standards. These latter methods may be carried out very rapidly and are reasonably accurate up to about 0·5% molybdenum, but above this value the accuracy decreases rapidly.

### A Simple Photometer

The introduction, in recent years, of various types of photoelectric absorptiometer has increased the speed and accuracy of the estimation. In many of the smaller laboratories, however, the amount of work done does not justify the purchase of one of these relatively expensive instruments, and in this paper it is proposed to describe the construction and operation of a simple photometer which may be assembled for a very small initial outlay. The instrument described has, as yet, been used solely for the determination of molybdenum in the range 0–1·0%, but may be applied to any of the current absorptiometric estimations of low alloying constituents. The accompanying diagram illustrates the photometer assembly.




P. Photocell.
Y. Photocell Hood.
F. Filter.
S.C. Solution Cell.
G. Mirror Galvanometer.
L. Lens.
D. Variable Aperture.
M. Lamp Mask.
X. 6-Volt Lamp.
A. 6 Volt Accumulator.

The lamp is masked in such a way that the area of illumination at the lens face is only slightly greater than the maximum diaphragm aperture. This eliminates any effects due to stray light striking the walls of the cabinet in which the instrument is housed and being reflected back on to the photocell. As a further precaution, the inside of the cabinet, lamp mask, photocell hood and any reflecting surfaces are treated with optical black. The lens and lamp are positioned so that an image of the lamp filament falls on the surface of the photocell. This ensures that the photocell area illuminated is constant at any aperture and eliminates effects due to differential fatigue over the cell surface. When the relative positions of lamp, lens and photocell have been ascertained, each should be firmly fixed to a rigid support to prevent accidental displacement. The cabinet used to house the photometer should have a door or hinged flap conveniently placed for the insertion of the optical cells and should be completely light-tight when closed.

The galvanometer is set to give zero deflection with the lamp switched off and the cabinet closed. A 1 cm. cell, containing water, and an Ilford filter No. 603 are now placed in position in the photometer and the lamp is switched on for 5 or 10 minutes to allow the photocell response to fall to a uniform value. The lens aperture is then adjusted to give a full scale deflection on the galvanometer. This aperture should be kept constant for all subsequent molybdenum estimations.

*Reagents required :—*

Perchloric Acid (60%).
Sulphuric Acid (1 : 4).
Sodium Thiocyanate (10% solution).
Stannous Chloride (10% solution in 5% hydrochloric acid).

*Note.*—The necessity for making up a fresh supply of stannous chloride solution each day may be overcome by storing the solution under an atmosphere of hydrogen.

### Procedure

0·5 gram of the sample are weighed into a 100 ml. beaker and dissolved by heating with 10 ml. of perchloric acid. When solution is complete, the beaker is heated strongly till dense white fumes are evolved. The

solution is then cooled, diluted with water to redissolve the salts, washed carefully into a 100 ml. graduated flask and made up to the mark with cold distilled water. After thorough mixing, a portion is filtered off through a dry No. 41 Whatman paper into a dry beaker. The reagent solutions are added from burettes to a clean dry beaker as follows :—

1. 25 ml. sulphuric acid (1 : 4).
2. 5 ml. sodium thiocyanate (10%).
3. 10 ml. of the sample solution (from a pipette).
4. 10 ml. stannous chloride (10%).

The colour becomes stable in less than five minutes under these conditions and shows no sign of fading at the end of one hour. After standing for five minutes, a clean dry 1 cm. cell is filled with the solution, inserted in the photometer and the reading taken with an Ilford No. 603 filter in position.

If the deflection is measured in centimetres, a graph must be constructed by plotting the deflections against % molybdenum for a series of samples of known molybdenum content. The molybdenum content of any subsequent sample is then obtained by reading off on the graph the % molybdenum corresponding to the deflection measured.

If, however, a logarithmic scale is used, the relationship between the deflection and the molybdenum content of the sample is linear and % molybdenum may be calculated from an empirically derived factor. The relationship between the absorption of light by a coloured solution and the concentration of the coloured substance is given by Beer's Law :—

$$T = \frac{I_2}{I_1} = 10^{-lcK_\lambda}$$

$$lcK_\lambda = \log_{10} \frac{I_1}{I_2}$$

Where $T$ = transmittance of solution
$l$ = thickness of solution layer
$c$ = concentration of absorbing substance
$I_1$ = initial light intensity
$I_2$ = emergent light intensity
$K_\lambda$ = a constant for wavelength $\lambda$.

$\therefore$ For a given thickness $l$

$$\text{Concentration} \propto \log_{10} \frac{I_1}{I_2}$$

$$\text{i.e.—Concentration} \propto \log_{10} \frac{\text{Full scale deflection (cms.)}}{\text{Deflection with sample (cms.) in position.}}$$

The scale is constructed according to the above relationship. If the full scale deflection is 10 cms., the logarithmic zero falls on the 10 cm. mark and the scale is marked out in values of $\log \frac{I_1}{I_2}$ as shown in the diagram.

If a logarithmic scale of this type is used, the factor is obtained by running through a number of samples of known molybdenum content and dividing the % molybdenum by the corresponding log scale deflection. The quotients are averaged and the mean figure is taken as the factor.

With practice the whole procedure may be carried out in 15-20 minutes. The method has been used successfully on irons containing up to 4·5% nickel and 1·0% chromium. The following comparison between photometric and chemical estimations gives some idea of the accuracy to be expected.

| Type of Iron | % Mo Photometric. | % Mo Gravimetric $\alpha$ Benzoin monoxime. |
|---|---|---|
| 1·5% Ni, 0·5% Cr | 0·23 | 0·21 |
| 0·3% Cr. | 0·73 | 0·71 |
| 4·5% Ni | 0·80 | 0·80 |
| 1·0% Cr. | 0·99 | 1·02 |

### Costs

Appended are a few notes on the approximate cost of the main items used in the photometer assembly. It should be noted, however, that the prices given for the mirror galvanometer and lamp and scale are pre-war. A self-contained spot galvanometer would probably be cheaper and more convenient to use.

| | £ | s. | d. |
|---|---|---|---|
| Photoelectric cell .. .. .. .. .. .. .. | 2 | 6 | 9 |
| Mirror galvanometer .. .. .. .. .. .. | 5 | 4 | 6 |
| Projector lamp and scale .. .. .. .. .. | 4 | 8 | 0 |
| Condensing lens and diaphragm .. .. .. .. | 4 | 10 | 0 |
| Three 2-volt accumulators (15/6 each).. .. .. | 2 | 6 | 6 |
| | £18 | 15 | 9 |

In conclusion, I wish to express my thanks to the Directors of the Sheepbridge Stokes Centrifugal Castings Co., Ltd., for permission to publish this paper, and to Mr. M. M. Hallett, the Chief Metallurgist, for his unfailing help and encouragement.

## Harper Meehanite Die Material

THE information given in this useful booklet is divided into two parts, the first part outlines the uses of Harper-Meehanite die material, and the second part gives useful press-shop engineering data and tables. Experimental efforts have been successfully directed toward the production of cast-to-form dies which will : (1) provide increased production life through better-wear resistance ; (2) cold work to a high polish and great surface hardness ; (3) be free from galling, scuffing, and scoring ; and (4) provide high strength and toughness combined with unusual endurance and compression. As a result of this experimental work it has been found that Harper-Meehanite die material is particularly suited to the making of press-tools and dies and many types of jigs and fixtures. Meehanite has a pearlite matrix and is therefore tough, and cast-to-form dies in this material are successfully solving many production, service life and cost problems. Some examples are given in this booklet, together with the properties of the material with suggestions for its most profitable use. Copies of this booklet, which is bound in board covers, may be obtained on application to John Harper (Meehanite), Ltd., Albion Works, Staffordshire.

## Evacuated Bimetal Switches

USEFUL data concerning bimetal switches is given in a pamphlet from Sunvic Controls, Ltd. Two types of switches are described : load-limiting switches and time-delay switches. They incorporate a number of unique features in their construction. Each switch is totally enclosed in a strong evacuated glass tube, thus arcing at the contacts is reduced to a minimum, oxidisation of the contacts is prevented and danger of explosion in locations where there are volatile vapours is eliminated. Further, the switch is silent in operation and the current required to operate it is small. Those interested should obtain a copy from Sunvic Controls, Ltd., 10 Essex Street, Strand, London, W.C.2, or telephone : Temple Bar 7064.

# MICROANALYSIS

## CHEMICAL AND PHYSICAL METHODS

APPARATUS  METALLURGICAL APPLICATIONS  TECHNIQUE

*"IT is very difficult to get a well-trained analytical chemist now. Very few of the college graduates now have ever made the simplest kind of mineral analysis . . . General analytical chemistry is too darn hard work for the average pampered youth. He wants a short cut . . . something very easy." Although this complaint comes from America, we could echo it with many similar complaints made to us over here. We remember one Professor who lamented to us a few years ago that it was difficult, if not impossible, to train many students to do any accurate work with a balance, while another teacher said that he often got the impression that his students, following the example of the old-time cobbler with his nails, filled their mouths with weights and from time to time spat one on to the balance-pan. The outlook is not so gloomy as the above might lead one to believe. Some institutions make every effort to give their students a sound groundwork in analytical chemistry, both theoretical and practical. And with the best students they succeed. However, it is the best, and not, as some chemists still persist in believing, the worst, who turn out to be good analytical men. Just to conclude, we cannot resist adding the concluding sentence to the quotation with which we opened. "He shuns weighing on an analytical balance, and prefers to guess at it with the spectrograph." We quote this as an example of an attitude of mind which is just as reactionary as that about which we have been complaining. The good man will use analytical balance and spectrograph with equal facility, each in its own place, and will guess at the result with neither.*

# Microdetermination of Zinc in Aluminium Alloys


D. F. Phillips and L. J. Holton

*Research Laboratories, High Duty Alloys, Ltd.*



*A recent paper by Townend and Whalley[1] describes a composite scheme for the microdetermination of copper, nickel, iron, silicon, titanium, and manganese in aluminium alloys. These are all absorptiometric procedures for which suitable aliquots are taken from a total volume of 10 ml. obtained after processing a 10 mg. sample The method described below for the microdetermination of zinc uses an aliquot of 0·5 ml. (equivalent to 0·5 mg. sample) from the 2·5 ml. remaining after determination of the above elements.*


IN a former article the authors describe an absorptiometric method for the determination of zinc in the presence of cobalt and traces of nickel using diphenylcarbazone.[2] The method depends on the extraction of the pink zinc-diphenylcarbazone complex with amyl alcohol from a solution containing ammonium chloride and sodium carbonate followed by measurement on the Spekker photo-electric absorptiometer.

The present article describes the application of this procedure to the microdetermination of zinc in aluminium alloys. As it was found that large amounts of aluminium and alloying amounts of copper, nickel, magnesium, iron, silicon and manganese caused interference with the previous method, modifications were introduced. These consist of additions prior to extraction of potassium cyanide, potassium fluoride and formaldoxime hydrochloride. It has been found expedient to combine these reagents together with ammonium chloride and sodium carbonate in a single suppressing solution the exact composition of which is given below. In view of the proposed application of the method to a variety of alloys which in addition to the above elements might also contain traces of titanium, lead, tin and chromium, it was necessary to establish that none of these elements caused interference. It is demonstrated by the results summarised in Tables I and II that the suppressing solution is completely effective in eliminating interference from all amounts of alloying elements likely to be encountered in commercial aluminium alloys. In all these experiments both aluminium and alloying elements were present in correct proportions assuming a 0·5 mg. weight of sample to be in solution.

1 Townend, J., and Whalley, C., *Metallurgia*, 1947 (June), **36**, 104.

2 Phillips, D. F., and Holton, L. J., *Metal Ind.*, 1948 (January) 23rd, **72**, 69.

**TABLE I.—EFFECT OF OTHER ELEMENTS PRESENT**

| Elements Present | Zinc. Added | Zinc. Found |
|---|---|---|
| 13% Cu | Nil | Nil |
| 13% Cu | 5·00% | 5·04% |
| 5% Ni | Nil | Nil |
| 5% Ni | 5·00% | 5·02% |
| 10% Mg | Nil | Nil |
| 10% Mg | 5·00% | 4·98% |
| 12% Si | Nil | 0·01% |
| 12% Si | 5·00% | 4·98% |
| 1·0% Fe | Nil | Nil |
| 1·0% Fe | 5·00% | 5·03% |
| 2·0% Mn | Nil | Nil |
| 2·0% Mn | 5·00% | 5·01% |
| 2·0% Mn | Nil | 0·50%* |
| 2·0% Mn | 5·00% | 5·46%* |
| 0·3% Pb | Nil | 0·03% |
| 0·3% Pb | 5·00% | 5·03% |
| 0·5% Sn | Nil | Nil |
| 0·5% Sn | 5·00% | 4·99% |
| 9·5% Cr | Nil | Nil |
| 0·5% Cr | 5·00% | 4·99% |
| 0·2% Ti | Nil | Nil |
| 0·2% Ti | 5·00% | 5·00% |

* These high results occurred when the formaldoxime hydrochloride was omitted from the suppressing solution.

**TABLE II.—EFFECT OF COMBINATIONS OF ELEMENTS**

| Cu | Ni | Mg | Fe | Si | Mn | Pb | Al | Zinc added | Zinc found |
|---|---|---|---|---|---|---|---|---|---|
| 12·0 | 2·0 | 0·5 | 1·0 | 1·0 | 1·5 | 0·2 | base | 4·00 | 4·03 |
| 4·0 | — | 1·0 | 0·5 | 12·0 | 1·5 | 0·2 | " | 4·00 | 3·98 |
| 4·0 | — | — | 0·5 | 6·0 | 1·5 | — | " | 5·00 | 4·97 |
| 1·0 | 2·0 | 6·0 | 1·5 | — | 0·5 | — | " | 3·00 | 3·00 |

## Working Details of Method

*Reagents required :*

1. Sodium hydroxide—40% solution.
2. Nitric acid—40% solution.
3. Ammonium chloride—20% solution of A.R. reagent.
4. Sodium carbonate—N/5 solution of A.R. reagent.
5. Formaldoxime hydrochloride—dissolve 1 g. pure reagent in 20 ml. water. Neutralise with litmus paper with N/5 sodium carbonate and dilute to W100 ml.
6. Potassium fluoride—1% solution freshly prepared each day.
7. Potassium cyanide—0·04% solution prepared immediately before use.
8. Amyl alcohol :- In order to ensure a sufficiently high standard of purity supplies should be tested as follows : to 1·0 ml. of a 0·1% solution of diphenylcarbazone in redistilled amyl alcohol add 9·0 ml. of the amyl alcohol under test. The resulting solution should be of a pale yellow colour. Should any trace of pink colour be detected the amyl alcohol must be redistilled.
9. Diphenylcarbazone extracting solution—0·1% solution in pure amyl alcohol.
10. Acetone.
11. Suppressing solutions :—Freshly prepared as follows :—To 110 ml. distilled water add :— 10 ml. ammonium chloride (Solution 3). 40 ml. freshly prepared potassium fluoride (Solution 6). 40 ml. sodium carbonate (Solution 4). 30 ml. formaldoxime hydrochloride (Solution 5). Transfer to a 300 ml. separating funnel and shake vigorously with about 30 ml. of diphenylcarbazone extracting solution (Solution 9) to purify the reagents. Allow to settle. Run off the aqueous layer into a beaker and reject the amyl alcohol layer. Re-extract the aqueous layer by shaking with a further 30 ml. diphenylcarbazone. Run off the aqueous layer into the beaker. Reject the amyl alcohol layer. Add 25 ml. potassium cyanide (Solution 7). Re-extract with a further 30 ml. diphenylcarbazone as before. This volume of solution is sufficient for about 10 determinations.

### Initial solution of sample

Weigh 10 mg. sample into a platinum or gold micro-beaker. Dissolve in 1·0 ml. 40% sodium hydroxide and evaporate to a low volume in order to effect complete solution of all the silicon present. Cool. Add 2 ml. water. Mix. Acidify with 2·25 ml. 40% nitric acid. Transfer to a graduated 10 ml. flask. Dilute to mark and mix well. A blank determination should be carried out on a 10 mg. sample of zinc-free aluminium.

### Extraction of zinc

Pipette 0·5 ml. ( = 0·5 mg. sample) into a 30 ml. beaker. Add 25 ml. suppressing solution and then 0·2 ml. acetone. Mix and stand for 5 minutes. Transfer to a 30 ml. separating funnel and run in from a burette 3 ml.

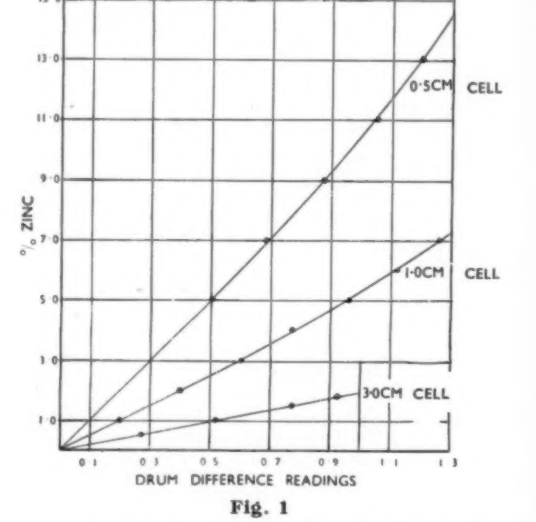



**Fig. 1**

**Graph for the Microchemical Determination of Zinc in Aluminium Alloys**

diphenylcarbazone extracting solution. Shake vigorously for 30 seconds. Allow to settle. Run off the aqueous layer into the original beaker and the amyl alcohol layer into a dry 25 ml. beaker. Return the aqueous layer to the separating funnel and repeat the extraction with 3 ml. diphenylcarbazone solution exactly as before. Altogether make 4 extractions with 3 ml. portions of reagent as above and combine all the amyl alcohol extracts in the 25 ml. beaker. Finally transfer the combined amyl alcohol extracts to the separating funnel washing in with amyl alcohol. Allow any remaining water to settle and carefully run off. Transfer the coloured amyl alcohol solution to a 25 ml. graduated flask, dilute to the mark with pure amyl alcohol and mix thoroughly.

### Details of absorptiometric measurement

Measure on a Spekker photo-electric absorptiometer using mercury lamp, heat-resisting filters (H503), and Ilford yellow-green filters 605. An appropriate neutral filter placed on the left-hand side is used to obtain increased sensitivity by compensating for the absorption of the yellow extracting solution.

The following cell sizes and drum settings have been found suitable for the various zinc ranges. In each case the setting solution used is the extract from a 0·5 ml. aliquot from the blank determination which has been treated as above.

Micro absorptiometer cells contained in an adaptor were used as recommended by Vaughan and Whalley[3] scheme, but if desired, sufficient solution is available to use normal macro cells.

| Cell Size | | Zinc Range | | Drum Setting |
|---|---|---|---|---|
| 3 cm. | .... | 0·0–2·0% | .... | 1·00 |
| 1 cm. | .... | 0·0–7·0% | .... | 1·30 |
| 0·5 cm. | .... | 0·0–14·0% | .... | 1·30 |

3 Vaughan, E. J., & Whalley, G., *J.I.S. Inst.*, 1947 (April), 5:7.

### Calibration graphs

Add varying amounts of standard zinc solution to 0·5 mg. portions of zinc-free aluminium alloy. Process, extract, and measure as above and construct calibration graphs. Typical calibration graphs are shown in Fig. 1.

### Results

Determinations were carried out on a selection of typical aluminium alloys and the results are summarised in Table III, which also shows percentages of other elements present. The zinc results by the above method are shown in comparison with those obtained by the well-established polarographic method of Stross.[4]

TABLE III.—DETERMINATION IN ACTUAL ALLOYS

| Alloy | Cu | Ni | Mg | Fe | Si | Ti | Mn | Pb | Cr | Sn | Zinc by Polarograph | Zinc by Diphenylcarbazone |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D.T.D. 424 (1) .. .. | 3·10 | 0·10 | 0·20 | 0·65 | 4·90 | 0·10 | 0·45 | 0·04 | — | 0·04 | 0·13 | 0·075 |
| D.T.D. 424 (2) .. .. | 3·80 | 0·21 | 0·10 | 0·70 | 4·50 | — | 0·52 | — | — | — | 0·32 | 0·31 |
| Duralumin .. .. .. | 4·15 | 0·22 | 0·53 | 0·81 | 0·71 | 0·08 | 0·54 | 0·01 | 0·07 | 0·01 | 0·26 | 0·23 |
| D.T.D. 428 .. .. .. | 7·33 | 0·27 | 0·09 | 0·90 | 2·65 | — | 0·38 | 0·09 | — | 0·04 | 2·99 | 3·02 |
| Hiduminium RR.88 .. | 2·04 | 0·02 | 2·58 | 0·39 | 0·35 | 0·015 | 0·45 | — | — | — | 4·89 | 5·00 |
| Hiduminium RR.77 .. | 0·43 | — | 2·65 | 0·19 | 0·16 | — | 0 ·50 | — | — | — | 5·42 | 5·33 |
| Experimental Binary No. 1 | — | — | — | 0·05 | — | — | — | — | — | — | 5·11 | 5·10 |
| " No. 2 | — | — | — | 0·04 | — | — | — | — | — | — | 7·38 | 7·21 |
| " No. 3 | — | — | — | 0·05 | — | — | — | — | — | — | 10·66 | 10·53 |

During the investigation numerous tests of colour stability were carried out, and in no case was fading or intensification observed up to 24 hours.

The authors are indebted to the directors of Messrs. High Duty Alloys, Ltd., in whose laboratories the method was developed, for permission to publish these results.

4 Stross, W., *Metallurgia*, 1947 (July), **36**, 163 (August), **36**, 223.

# An All-Purpose Drying Oven for use in Micro-chemical Analysis

G. Ingram

*A new drying oven for filter-sticks and beakers is described, together with additional apparatus which may be used in filtration and drying technique.*

THE conventional type of micro-oven designed by Benedetti-Pichler[1] and since modified by Colson[2] though simple in construction has one or two faults connected with the method of attachment of the filter-stick to the suction source. As the beaker is inserted horizontally into the oven there is a danger that some loss of the contents may occur during its removal after drying. Also as the drier is constructed from glass tubing, direct heating with a flame is not permissible and a metal heating block is necessary. The drier described below eliminates these difficulties, being itself constructed of metal, and because a simple method is used to attach the filter-stick to the suction source. This is accomplished by modifying the filter-stick to the extent of fusing a small flange on the stem about 15 mm. from the end (Fig. 5A).

Other drying procedures such as drying crucibles and even determining the loss in weight of a substance can be carried out with the drier by using a second lid supporting a tiered stand.

Other apparatus described are a metal cooling block and a bell jar suction vessel.

1 Benedetti-Pichler, A. Mikrochemie, Pregl Festschrift, 1929, 6.
2 Colson, A. F., *Analyst*, 1946, **71**, 322.

### The Micro-Oven

The drier illustrated in Fig. 1 is made from a cylindrical aluminium block 5 cm. in diameter and 10 cm. long, bored to a depth of 8 cm. and 4 cm. in width, and is mounted vertically on a supporting stand housing a micro-burner B fitted with a fine control device. The main chamber has an outlet C for connection to a drying tube and dust filter, whilst the solid base D is bored for a thermometer.

When filter-sticks and their beakers are to be dried the lid shown in Fig. 2 is used. The lid is made of heat-resisting material hollowed out as shown at A, and

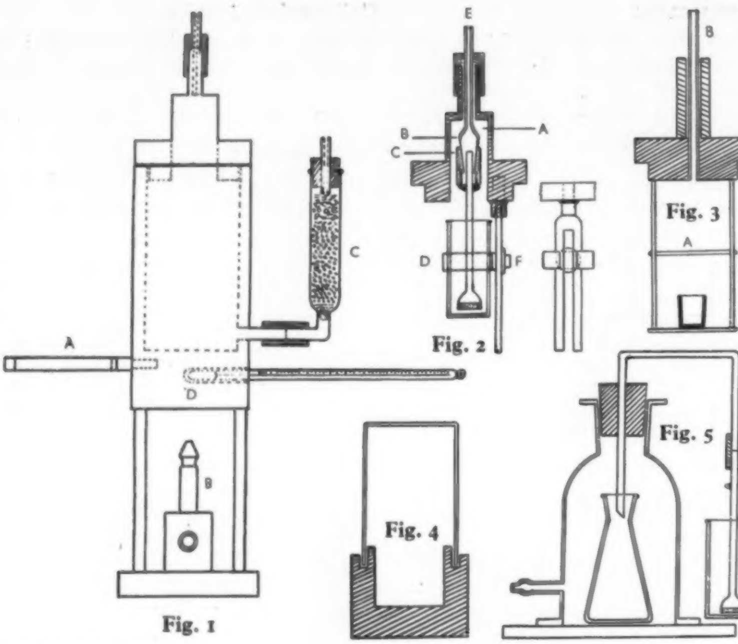



**Fig. 1.**—**The drier.**

**Fig. 2.**—**Design of lid for drying filter-sticks and their beakers.**

**Fig. 3.**—**Lid for supporting tiered stands.**

**Fig. 4.**—**Beaker cooling block.**

**Fig. 5.**—**Design of suction vessel.**

contains a glass suction tube B fitted with a rubber collar C at its enlarged end. In operation, the beaker is held in the adjustable clip D whilst the filter-stick is pushed up the suction tube, as shown in the diagram, until its flange becomes flush with the rubber collar. When suction is applied at E the filter-stick is held firm but is released when discontinued, so that it drops freely when the beaker is lowered from its clip. Different sized beakers require appropriate sized clips which are detached from the slotted support by loosening the screw F. When the beaker and contents have been dried sufficiently the lid is removed from the oven, placed in the ring support (Fig. 1A), which is fitted to the side of the drier, and allowed to cool before being removed to its cooling block, shown in the diagram (Fig. 4).

A metal lid for supporting the tiered stand (Fig. 3A) is required so that a good vacuum tight fit is obtained when substances have to be dried in vacuo. The suction lead B, used when crucibles or substances are dried in a stream of dry air, is attached to the lid and passes through a short cylindrical block of heat-insulating material which serves as a handle when the lid is removed from the oven. To maintain a vacuum in the oven the suction lead is closed with a stopcock and the vacuum line attached to the drying tube outlet (Fig. 1C).

### The Bell Jar Filtration Apparatus

The suction vessel shown in the diagram (Fig. 5) is a more convenient pattern than the conventional test tube as it is suitable for enclosing either micro-beakers, crucibles, small evaporating dishes and conical flasks for collecting filtrates. It has an overall height of about 10 cm. and 5 cm. in diameter and the wide open end is flanged and ground flat on a 10cm. square of plate glass giving a vacuum-tight movable bottom. To ensure rigidity when connected to the vacuum line the side-arm is situated just above the flange. The neck also terminates with a flange to allow the use of a rubber pad 5 mm. thick bored with a small hole for the insertion of the stem of micro-sintered filter-tunnels. A rubber bung may be used for filter-tubes, crucibles and filter-sticks.

### The Cooling Block

The cooling block (Fig. 4) consists of a cylindrical block of aluminium 5 cm. in diameter and 4 cm. high, bored to a depth of 2·5 cm. and about 3 cm. wide. A dust cover is provided, made from a 6 cm. length of glass tubing which rests in the slotted ring surrounding the edge of the block.

## Load-Carrying Capacity of Frame Structures

### The Behaviour of the Double Curvature Stanchion

The British Welding Research Association has issued the Sixth Interim Report* of the F.E./1 Committee on the load-carrying capacity of frame structures, which gives further consideration to the behaviour of the double curvature stanchion, and contains an account of the derivation of approximate expressions for the determination of the axial load to cause collapse. A comprehensive series of tests on stanchions subjected to this form of bending was described in the Fifth Interim Report, the behaviour of the single curvature stanchion having been studied in an earlier investigation.

It was shown that when a stanchion is bent in single curvature the effect of an increasing axial load is to cause yielding to occur first on the centre of length. By making certain simplifying assumptions in the range of loading beyond, it was possible to carry out a complete analysis of each test and hence to give an explanation of behaviour of the single curvature stanchion right up to collapse. With this knowledge it was not a difficult matter to derive approximate expressions from which collapse loads can be calculated with satisfactory accuracy. In double curvature bending, yielding occurs first at the ends of the stanchion, and under these conditions it was not found possible to make any simplifying assumptions. However, despite this difficulty, sufficient information was forthcoming from the tests to justify certain arbitrary assumptions in deriving approximate expressions for determining collapse loads of stanchions bent in double curvature. Values obtained in this way have been compared with the observed collapse loads for a number of the test specimens described in the Fifth Interim Report.

* Welding Research Supplement to the Transactions of the Institute of Welding, Aug., 1948.

# Copper-Aluminium Joints and Combination Materials Made by Upset Welding

By R. T. Gillette

THE development of upset welding of copper to aluminium has been occasioned by the need of attaching a copper end to an aluminium coil for intercoil connections, and making connection to coil terminals in electrical applications. Mechanical joints in time may build up an oxide film and develop high electrical resistance, causing heating which might progress to a point of failure of the mechanical joint because of arcing and melting.

The use of solder has not been practical since a soldered joint on aluminium can fail because of electrolytic corrosion resulting under some conditions of high humidity and contaminated atmospheres. Also, a soldered joint has little strength at the temperatures at which some of these joints might be required to operate.

The development was started on a manually operated butt welder, and after a few trials a ductile weld was produced which could be bent back double at the joint. This gave enough encouragement to continue the investigation, and after a considerable time the following factors were determined.

It is well known that alloys of copper with more than a few per cent. of aluminium become excessively hard and brittle, and that alloys of aluminium with more than a few per cent. of copper are likewise hard and brittle.

Interpreted into weld joint efficiency, this meant that a joint had to be produced either with no alloy or with a microscopically thin layer of alloy with low concentration of one metal in the other. It was found that such a joint could be produced by the following procedure.

The samples were prepared with a square end by machining. They were then clamped in the welder with approximately 1 in. overhand of the metal between the clamps. Just enough pressure was then applied to prevent arcing when the current was applied. The current was applied for a sufficient time to melt the metal at the interfaces still retaining low pressure. When the proper temperature was reached, the pressure was suddenly increased and the current switched off at the same time.

The quick increase in pressure almost completely extrudes the alloy from the joint, leaving a sharp line of demarcation between the copper and aluminium, and producing a ductile weld.

If high upset pressures are used for the entire time of making a weld, as the aluminium starts to soften due to its heating, it will upset like a flat head rivet before it becomes hot enough to weld at all.

If low pressure is used during the entire welding cycle, the copper aluminium alloy will not be extruded from the joint, and the resultant weld will be too brittle to be of any value.

After determining these factors on a manually operated machine, a fully automatic welder was designed and built, as it was found that the results on the manually operated welder were erratic because of the human element.

In making this weld, heat balance is another factor that must be considered. As aluminium melts at approximately 1,210° F. and copper at 1,981° F., and the electrical conductivity of aluminium is about 61% that of copper and the same welding current must be used to heat both, some compensation must be made to prevent the aluminium from melting and running from the joint before the copper is hot enough to weld. This is accomplished by having about three times as much copper as aluminium protruding from the welding clamps.

From tests it appears that the welded joints are practically the equivalent of the straight aluminium and that subjecting them to salt spray or steam did not lower their properties. The joints were also tested for their electrical resistance. No joint resistance was detected with the samples tested.

These joints also behave satisfactorily under vibration, but due to the abrupt transition from the hard copper to the soft aluminium are not too satisfactory under severe shock.

There is one caution to be observed in any subsequent work or fabrication in close proximity to these joints, such as welding, brazing or heat treating procedures. That is not to bring the copper-aluminium joint above the melting point of the copper aluminium eutectic alloy, about 1,018° F., as copper-aluminium in such intimate contact will rapidly diffuse into each other and form a layer of eutectic alloy which will melt at the eutectic alloy melting point, and thus the joint fails.

This joint was primarily developed to further the substitution of aluminium for copper coils on heavy high-speed rotating electrical equipment, where the rotating parts may weigh many tons. The use of aluminium reduces the weight of the coils approximately 50%, which is of major importance in lowering centrifugal stresses.

This type of joint is also used on the moving coil of an electrical measuring instrument wound with aluminium wire 0·005 in. in dia., replacing a copper winding. The reduction in weight reduces inertia so the needle will come to rest with a minimum of swing. This coil weighs only 0·1655 gram. Two small strips of thinly-rolled (0·003 in.) copper-aluminium are used to connect the aluminium wires to the terminals, by folding over the aluminium end of the strip and spot-welding the aluminium wire between the fold, and then soldering the copper end to the coil terminal. This method gives a permanent joint not susceptible to electrolytic corrosion.

This method of welding has been used for several other applications of an entirely different nature than coil weight reduction, where it is desirable

From *Materials and Methods*, **28** July, 1948. Pp. 70–73.

to use aluminium to replace copper for various reasons. But a partial use of copper is required for ease of fabrication.

In refrigeration it is sometimes desirable to use aluminium for evaporators or condensers, as it may have better sanitary properties in various foods acids, lower cost than some other non-corrosive materials, better heat conductivity, and be more readily available. In making up the pipe connections between these and other parts of the refrigerating system, it is common practice to weld together a piece of copper tubing and a piece of aluminium tubing as a unit. These units may then have the aluminium tube welded to the aluminium fabricated part, and the copper tube end may be soldered, brazed, welded or used in a mechanical connection to connect to the compressor or other part of the system. These joints may also be used on bus bars, cable splicers, connectors, terminals, chemical equipment, and electrolytic cells.

The development of upset welding of copper to aluminium opens up a new method of fabrication which should find wide use wherever it is desired to join copper to aluminium but where the other welding processes would result in a brittle weak joint because of the inclusion of copper and aluminium alloys.

## Tonnage Oxygen

THE successful development of a new process for the manufacture of tonnage oxygen has been revealed by the Elliott Company, Jeannette, Pa. This development consumed approximately three years and has culminated in the completion of a pilot plant for 95% purity gaseous oxygen. The Elliott process is said to be a completely new system and differs in principle from systems developed abroad and now used in this country.

According to Elliott, the outstanding features of the process are as follows:

1. The plant is not subjected to the necessity for periodic shutdowns for deriming in order to remove accumulated deposits of water and carbon dioxide. This is important when oxygen is to be used in a process which must be kept on stream continuously.

2. The system is completely immune to possible dangers of acetylene explosions since this system provides a straight-forward and simple mechanical means of eliminating dangerous hydrocarbons from the system.

3. The process operates at reduced loads without sacrifice of efficiency.

4. The system is mechanically simplified. Like many other oxygen processes it depends upon reversing heat exchangers to precool the air to liquefaction temperature and at the same time freeze out water vapour and carbon dioxide. These accumulated deposits are periodically removed by reverse flow of effluent nitrogen. In this system these reversals take place every three to four hours instead of every two to three minutes as is common in other known systems. Heat exchangers in this system require only one hot and one cold gas as contrasted to the multifluid exchangers required by existing processes. The switching valves in this system function less frequently than in other systems, and are also designed to operate at only slightly above atmospheric pressure. This feature reduces maintenance cost and gives added assurance of long life in service without mechanical failure.

From *Mechanical Engineering*, June, 1948.

5. All controls are automatic. They can be set to maintain constant purity over the entire range of operating conditions, or the purity can be varied at will by a simply adjustment. The automatic controls on the plant can be arranged so that the oxygen plant will automatically follow the process demands for oxygen without requiring manual attention from the operators

6. The recovery of oxygen from the air is more than 97%, with the result that minimum power is wasted and the nitrogen leaving the process is sufficiently pure for use as a chemical raw material for the manufacture of ammonia, nitric acid, fertilisers, or other processes requiring high-purity nitrogen gas. The system will simultaneously produce high-purity oxygen and high-purity nitrogen.

7. Oxygen as pure as 99·5% can be made by the process. For tonnage production of commercial purity oxygen, analysis shows that it is more economical with the Elliott cycle to make 95 to 97% purity oxygen and to dilute the product as required for the subsequent process. A plant designed for 95% purity can also simultaneously produce 99·5% purity welding-grade oxygen in quantities as required for this purpose.

It is stated that the power requirements and capital cost for the system should compare favourably with other systems.

The Elliott process is a truly low-pressure system in which the air is compressed to about 5 psig, conditioned, and cooled to below-300° F., and charged to a single fractionating column. The complete distillation takes place within this column which operates only a few pounds above atmospheric pressure. The entire plant is controlled by temperature distribution and liquid levels within the fractionating column so that all controls can be related to the desired purity and optimum distillation conditions for minimum power consumption. The gaseous oxygen is boiled off from the reboiler and delivered as the product at approximately atmospheric pressure after having been warmed up to room temperature in a heat exchanger. Effluent nitrogen from the top of the fractioning column which contains not more than 0·5% oxygen is used to provide the refrigeration for precooling the air entering the process. A small portion of this nitrogen is used for the removal of the deposited impurities from the heat exchangers while the bulk of it is available at approximately 99·5% purity as a nitrogen product.

Like other oxygen systems refrigeration at extremely low temperature levels must be provided in order to make up for the warm end-temperature losses and the heat leak through the insulation into the system. This is accomplished in the system by an external refrigeration cycle which recirculates pure nitrogen from the top of the column through a heat-exchanger and compressor system, and finally obtaining the required amount of refrigeration by expansion through an Elliott turbo-expander. This same external refrigeration system is also arranged to produce the liquid-nitrogen reflux required as overhead in the column for distillation. The unique arrangement of components provides for control of the refrigeration and reflux independently of the quantity of air being charged to the system for distillation, so that the controls will automatically compensate for changes in demand and weather conditions for uniformity of product and minimum use of power.

The Elliott pilot plant has completed a continuous nine-week run during which time the operation was entirely automatic except during periods of obtaining special test data. The performance confirmed the correctness of design and from the analysis of the data obtained it was demonstrated that the plant could run indefinitely. Regular acetylene analyses were made throughout the process and at no time was any trace of acetylene ever found in the liquid oxygen where the explosion hazard would exist.

The possibilities of these oxygen plants are intriguing and commercial plants are envisioned which will produce more than 25,000,000 cu. ft. (1,000 tons) of oxygen per day. It is expected that with the use of oxygen the output and economy of open-hearth furnaces, blast furnaces, Bessemer converters, and electric furnaces can be greatly increased.

Quantity oxygen is also an essential of the new synthetic gasoline processes which are being planned. The use of oxygen combined with natural gas opens up a new source of supply of much-needed gasoline, fuel oil, and chemicals. Coal can also be used instead of natural gas, in the production of gasoline and fuel oil, and it is said this development can make the United States entirely independent of the rest of the world for liquid fuels for possibly as long as 1,000 years. Even substitute natural gas can be made right at the mines by the gasification of coal through the use of oxygen, and piped to large cities and industries.

# Radio-active Tracers

A NEW phase in use of radio-active tracers for industrial research is indicated by the recent completion of what is said to be largest tracer experiment ever conducted, and probably the first using full-scale industrial equipment. Sponsored by the Republic Steel Corporation, the experiment was conducted in their Cleveland, Ohio, plant by Arthur D. Little, Inc., Cambridge, Mass. The use of tracers in industry is reported to have increased greatly in the year and a half since the Atomic Energy Commission has made many new kinds available at lower prices.

The recent study was one stop in a programme for keeping undesirable sulphur out of steel, and is typical of the instances where tracers are especially useful. Sulphur enters steel in many ways—with the coke derived from coal, or with ore, limestone, scrap, or fuel oil. Some of it leaves the system in slag or flue gases, but some reaches the finished steel. In the finished steel, one cannot tell which raw material supplied the sulphur, except by tedious and inconclusive statistical correlation of sulphur content of the raw materials with that of the steel. This method showed coal to be the chief cause, but steelmakers still were not certain which of the chemical forms of sulphur in the coal got through to the coke and then entered the blast furnace.

There are two important forms of sulphur in coal, pyritic and organic. Since the forms change in the coke oven, there is no chemical method for learning whether the surviving sulphur in the coke came from the original pyritic or organic sulphur, or whether low-pyritic coal or low-organic coal is the better raw material. If one of the forms is tagged with radio-active atoms, however, its travels can be followed very precisely with radio-activity counters. In the present work, a small amount of artificial pyrites was made from radio-active sulphur and thoroughly mixed with 12 tons of coal, the normal charge to a coke oven. The proportion of the coke's sulphur

From *Mechanical Engineering*, June, 1948.

which had come from the pyrites was then found by measuring the radio-activity of the sulphur. This proportion was about the same as in the original coal, indicating that both forms are carried over to the coke equally, and that there is no advantage in buying coal with a low pyritic-sulphur content. More tests are planned to trace sulphur in other materials and chemical combinations through the steelmaking process.

Use of tracers to control industrial processes is being considered. As an example, radio-active phosphorus added to a Bessemer steel furnace would show when the last impurity, usually phosphorus, had been removed from the steel. Automatic controls could also be connected electrically to radio-activity-measuring instruments to turn down and shut off the Bessemer at the right time.

Research with tracers is characterised by directness and simplicity. Often, as in the coke-oven work, the experiment can be run in full-scale equipment. This is important, for there is sometimes serious doubt whether a conclusion reached in the laboratory will hold in the plant itself. Radio-active materials from the atomic pile are not expensive. The sulphur for this study cost about $50, compared with thousands of dollars pre-war, when radio-active materials were made in the cyclotron. Better measuring instruments are available now, and more technologists are familiar with radio-activity.

On the other hand, not all elements have radio-active forms suitable for tracer uses. For example, radio-active oxygen loses about half its radio-activity every two minutes. Many important radio-active elements are not available from the atomic pile, and must still be synthesised in a cyclotron at much greater cost. The A.E.C. restricts purchase and use of radio-active elements to protect the experimenter and the general public against misuse. The Commission considers the applicant's professional qualifications, the instruments available for safeguarding health, and the intended use. The requirements of the A.E.C. reflect the danger possible with radio-active materials. A properly planned experiment should involve precautions such as the use of a minimum amount of active material, appropriate shielding, avoidance of inhalation and ingestion of the material, and safe disposal of all waste containing active materials.

# Examination of Aluminium Conductor Cables after 15-25 Years' Service

By J. Herenguel

THE extensive repairs carried out on the French grid after the war provided an opportunity for the research centre of the Société des Trefileries et Laminoirs du Havre to examine specimens of their Almélec and aluminium-steel conductors which had been in service in various parts of France. Almélec is an aluminium alloy containing 0·7% magnesium, 0·5% silicon and 0·3% iron. It was specially developed for electrical purposes about 1927 and has a conductivity 52% that of copper.

Almélec conductors examined ranged in size from 12 mm.² to 210 mm.² in cross-section and, in many cases, it was possible to compare specimens with samples that had been in store for a similar period. After 17 years' service, the corrosion-resistance of the wire, under normal atmospheric conditions, was found to be completely satisfactory. No change in the mechanical properties had been caused by the electrical heating of the conductors.

The use of steel-cored aluminium conductors has been common practice in France for a period of over 20 years. Aluminium of purity 99·5% is used which gives an electrical conductivity of more than 60% that of copper. On almost all the specimens examined from various parts of the country, the outer layers of aluminium, which were exposed to the atmosphere, were covered with a thin, black adherent film which flaked off on bending the wire. This film contained about 50% free carbon, but had not given rise to any marked corrosion of the aluminium with the formation of characteristic white alumina. While conductors in service for some 13 years close to the Mediterranean coast showed no signs of corrosion, it is thought that some investigation should be made into the performance of conductors in sea air.

Nearly all the specimens of galvanised wire examined showed no deterioration of surface since installation. Specimens which had not been greased in the stranding process had a whitish appearance, but the metallic sheen reappeared on rubbing lightly. The mean thickness of the zinc coating expressed in g./dm.² of wire surface was determined for all specimens. In one case, which showed an intact outer layer of aluminium, the galvanised coating was found to be strongly attacked, and rust had appeared on the steel wire. Analysis revealed the presence of considerable quantities of chlorides probably brought about by some faulty galvanising operation.

The observations made on galvanised wire have indicated that some revision is desirable for specifications covering the galvanising of wire, with particular reference to the minimum thickness of the deposit and the necessity for avoiding the presence of chlorides. The number of layers of aluminium and the diameter of the wire are not thought to affect the life-time of the underlying galvanising.

Numerous tensile tests were carried out on the different layers of aluminium wire and comparison of the figures obtained with the original specified values showed no alteration in the mechanical properties. There was thus no evidence of annealing due to current heating or of corrosion.

In conclusion, the authors stress that S.C.A. conductors have given a high standard of service over the past period of 15–25 years and they estimate a satisfactory lifetime of 50 years for the conductors.

From *Revue de l'Aluminium*, December, 1947, pp. 357–360, and March, 1948, pp. 73–78.
Abstracted in *Light Metals Review*, 1948, 7, No. 8 and 13.

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